Control ENGINEERING

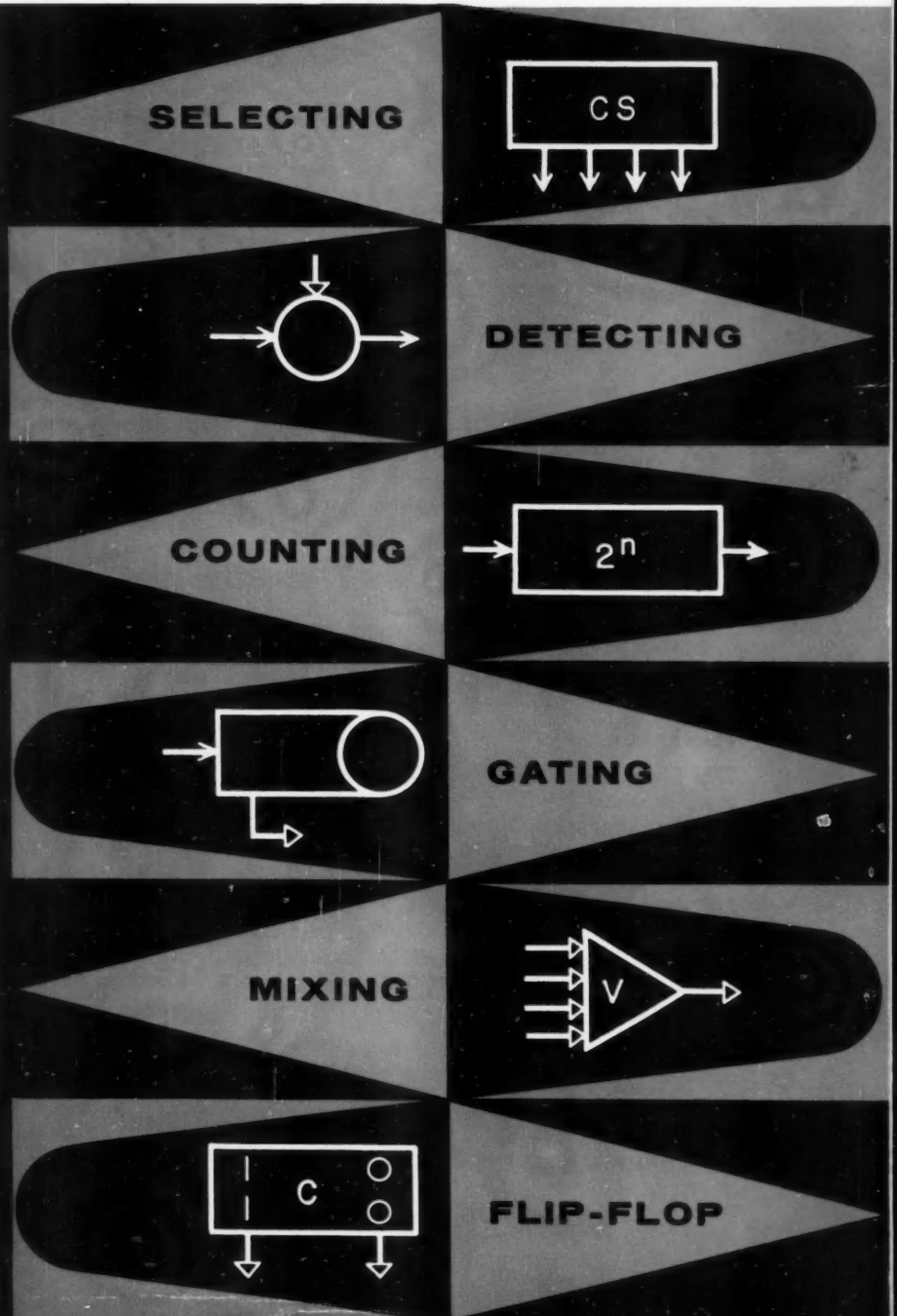
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 50 CENTS

JULY 1955

Putting PULSES to work..



SPECIAL INSERT

A COMPLETE SYSTEMS ANALYSIS

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made to JUMP TO CONCLUSIONS!

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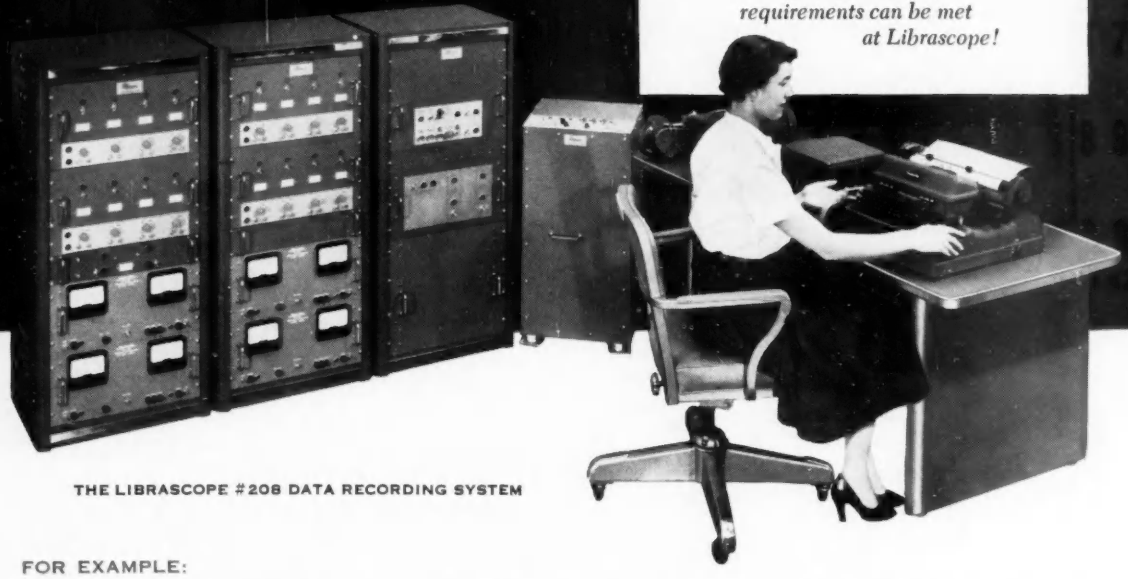

THE LIBRASCOPE #208 DATA RECORDING SYSTEM

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This Librascope Data Recording System is a high speed reduction system for the rapid conversion of multiple analog data to digital presentation on punched paper tape, magnetic tape or punched cards. This system, capable of operating at extremely high speed with utmost efficiency, can handle as many as 100 inputs and can be programmed for fast or slow sampling intervals. Designed to provide extreme flexibility in operation, this precise data handling system will accept a wide variety of inputs and is adaptable to any coded decimal or straight binary output. The broad versatility of this equipment permits a multitude of applications to military and commercial projects ranging from wind tunnel recording to the automatic control of industrial processes. For the most direct and effective solution to *your* particular data-handling or data-recording problem, consult Librascope's engineering staff. For further information, write today.

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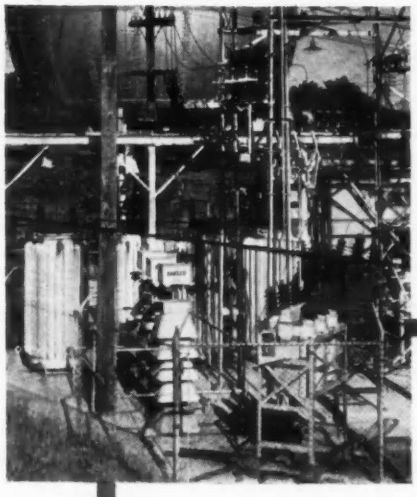
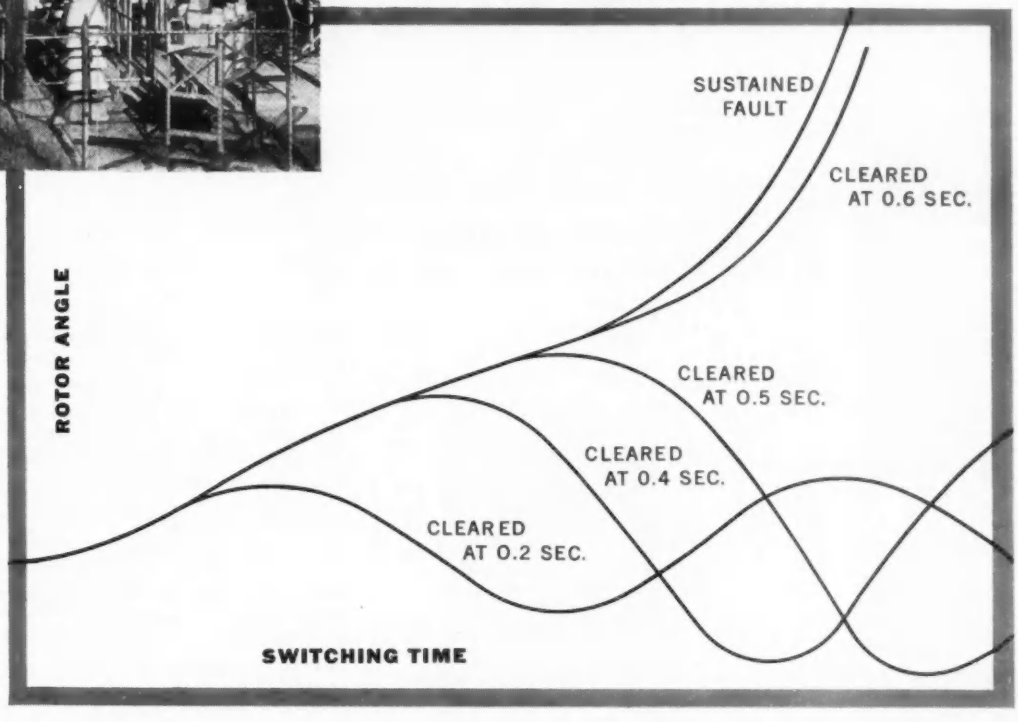


GEDA

solves control problems

for example:



How long can a breaker take to break?

WHEN a short circuit occurs on a power system, a circuit breaker goes into operation–opening or "clearing" the fault while protecting the generator. However, the circuit breaker requires a certain amount of time to operate. If the time is too long, the generator will slow down until it gets "out of step" with the rest of the system.

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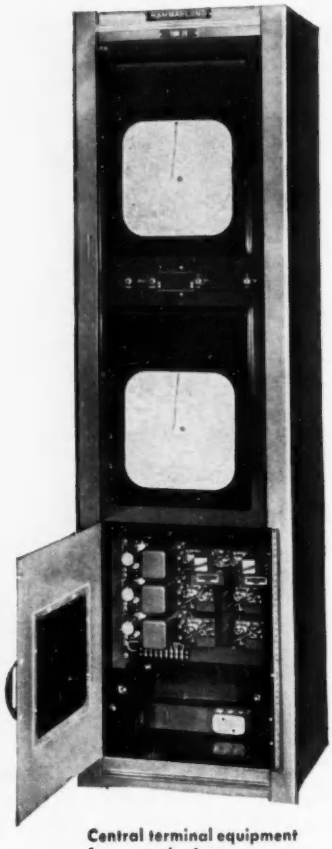
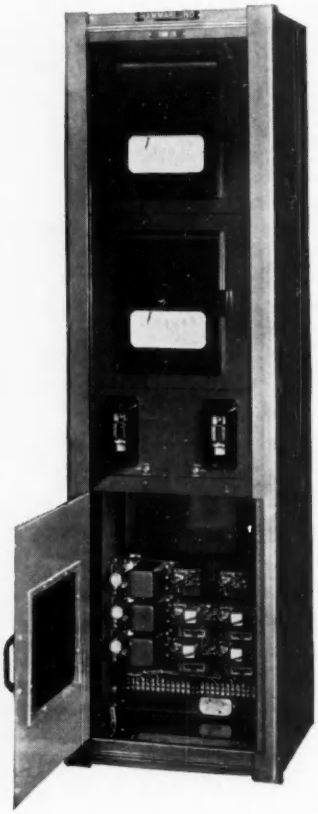
GOODYEAR AIRCRAFT

Centralized Operations Control...

Remote Supervisory Controls For Industrial & Governmental Use



Central terminal equipment for control of remote operations and display of telemetered information.



Remote terminal equipment. Operates in response to signals received from the central control point to perform ON-OFF and OPEN-CLOSE operations and returns metered data. Local control and indicating meters are also included.

- ***Puts all controls and metering in your central office.***
- ***Provides simultaneous and continuous operations.***
- ***Uses your present instruments if desired.***
- ***Uses just one telephone circuit or radio channel.***
- ***Is tested, proven, and safe.***

Your present equipment can be integrated into a Centralized Operation Control system. What COC does is modernize it to the extent that all your normal control and telemetering operations can be handled from a single central point over a single telephone circuit. Or, radio or microwave may be used.

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And, you don't have to have an electronics specialist on the job to operate your COC system. Once installed, any capable communications service man, electrician or instruments man can service it.

COC systems are flexible. All units are open-ended for future expansion. An almost unlimited number of functions are possible, but you buy only what you need at the start.

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Ask for Bulletin CC-11

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Control ENGINEERING

JULY 1955

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

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ADVERTISING INDEX 140

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SHOPTALK

SYSTEMS ANALYSIS—WITH ALL STOPS OUT

Since its start, CONTROL ENGINEERING has tried to do its bit for systems analysis in limited magazine space. But some readers have been clamoring for the whole story. So we've cornered the tinted paper market and in this issue present a *complete* systems analysis case history. It starts on page 65. It all began when Bill Vannah recalled field chats with Sverdrup and Parcel engineers about their epic analysis of a wind tunnel. Bill asked them to compile a junior-sized version of one portion of this job for us. They complied. A very bulky MS came through the mail and Ed Kompass spent the better part of a week organizing it to a trim but telling 16 pp.

EDITORIAL HAT TRICK

In early September our staff will attempt the neatest editorial hat trick of the month. They will be on hand in our booth at the Production Engineering Show on Chicago's Navy Pier, Sept. 6–16. And they will also occupy our booth at the ISA Exhibit in Los Angeles' Shrine Auditorium, Sept. 10–16. Oh, yes. They do have the October issue to get out at the same time in New York.

OUR DOWN-EASTER SOWS AND REAPS SOME ODES

Watch Bill Vannah and you'll get a lesson in the Law of Conservation of Energy. On May 17 he addressed a crowded grand ballroom in New York's Hotel Commodore on "Automation: Myth or Miracle?" Questions from the American Management Association audience were thick and fast. Bill countered well and then sidled up to the voicescriber and got copies of all queries. The reason? With Maine astuteness, Bill saw how to get real mileage out of his stint on the podium. His idea? A round-up based on the questions, which we'll publish soon.

GENE HAS HIS SAY

Consulting Editor Eugene Grabbe firmly believes that the control engineer has a future in business data processing. What's more, Gene can back up his belief—since he's a topnotch control engineer and computer specialist. And a highly articulate one at that. So we are delighted to have Dr. Grabbe air his favorite theme as guest editorialist this month. Read it on page 47.

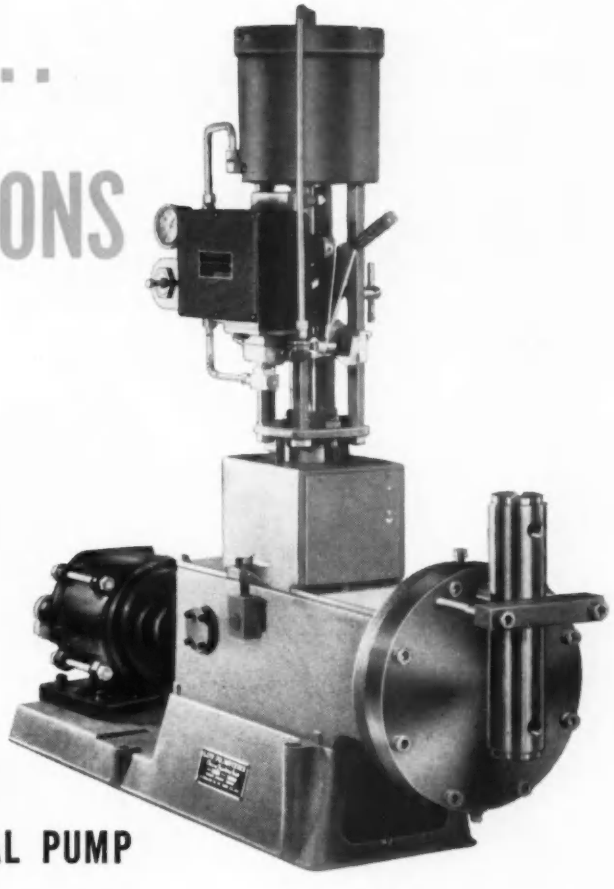
IT PUMPS...

IT METERS...

IT PROPORTIONS

IT FEEDS...

WITHOUT LEAKAGE OR CONTAMINATION



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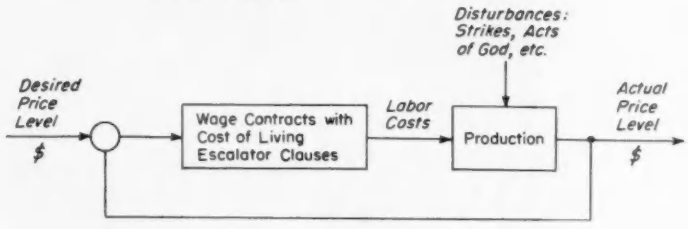
FEEDBACK

Now Here's An Economy Look



TO THE EDITOR—

Apropos of Russ's diagram on page 4 of the April issue, here is one, a very simple one, which has completely baffled me:

(See cut above)

No wonder the economy is unstable—the feedback is hooked up backwards.

Grosvenor M. Cross
Brooklyn, N. Y.

According to Mr. Cross's diagram, the reason for spiraling wages is that the feedback of living costs to wage contracts is regenerative. In the interest of stabilizing the economy, we suggest to collective bargaining technicians that they reverse the feedback from positive to negative.–Ed.

Timely, Terse, But in Reverse

TO THE EDITOR—

I enjoyed your article [May issue] on "Error Analysis During Design" by William Allison very much, in spite of the fact that the pages were transposed. This article came at a very opportune time, insofar as we are concerned, since we have completed a

• • •

PROBLEM FORUM

Last month's prize problem came from Germany. You'll see its solution in August. And now we have a French poser on temperature response in ovens. Let's have your answers. And some domestic queries, too. They may bring you a few dollars.

July's Prize Problem

TO THE EDITOR—

Show how to determine, by mathematical or graphical analysis, the temperature response of various types of ovens:

radiation oven
oven with burners
KRYPTOL oven (complicated because heating resistance decreases with temperature).

The engineer of a study bureau is often not equipped to handle problems of this kind. Misunderstanding of the principles of calculation leads to grave errors in application.

Societe d'Electro-Chimie, D'Electro-Metallurgie et Des Acieres Electriques d'Ugine
Lyon, France

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rather exhaustive search for material on this subject and found it in short supply.

We were rather disappointed to see that this article contained no bibliography. Since nearly all other articles in your magazine contain bibliographies, we feel that there may have been an omission in this case. If this is so, we would like to have a copy of the bibliography.

C. L. Opitz
Stavid Engineering, Inc.
Plainfield, N. J.

Author Allison, responding to reader feedback, offers the following bibliography on error analysis and probability—Ed.

1. **Introduction to Mathematical Probability, Uspensky, McGraw-Hill Book Co.**
2. **Sequential Analysis, Wald, John Wiley & Sons, Inc.**
3. **Components Handbook, MIT Radiation Laboratory Series, Blackburn, McGraw-Hill Book Co.**
4. **Treatment of Experimental Data, Worthing & Gaffner, John Wiley & Sons, Inc.**

Practice Makes Perfect

To the Editor—

At the Network Synthesis Symposium in April, the panel group of experts on "The Practical Implications of Synthesis" agreed almost unanimously that the way to get synthesis used by practicing engineers was to write articles they could understand in magazines the engineers read. So you're right up in the vanguard. . . .

Dr. Louis Weinberg
Hughes Research & Development
Radar Division
Culver City, Calif.

A Matter of Taste

To the Editor—

Whose idiotic idea was that horrible COLOR on this month's (May) cover?

Will you use limed green on the June cover? It blends well, you know, on old girls' hats. . . .

A Horrified Subscriber
Toronto, Ontario, Can.

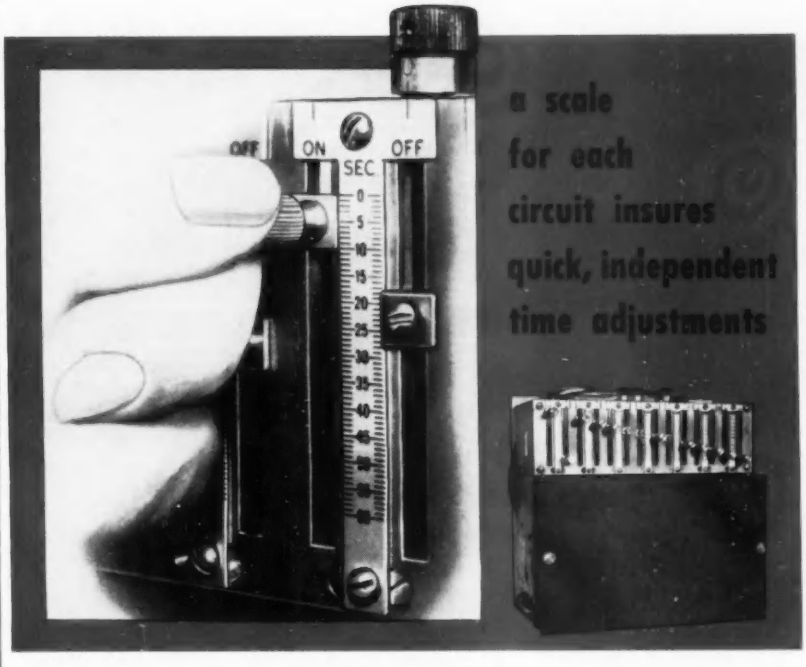
The cover color for May was magenta, in honor of George Boehm, our former Managing Editor. Thank you for suggesting a cover color for another issue.—Ed.

Boil and Bubble

To the Editor—

I should like to bring to your attention a type of automatic control

EAGLE MULTIFLEX
(multiple circuit) reset timer



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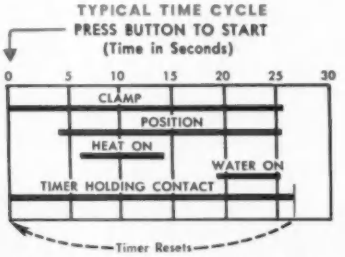

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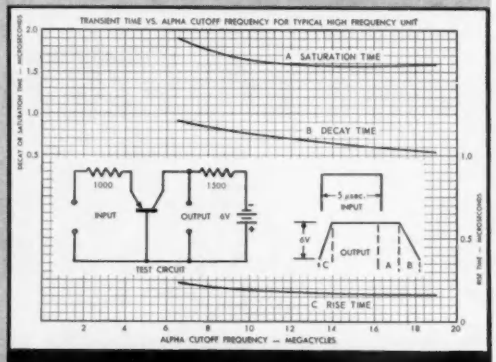

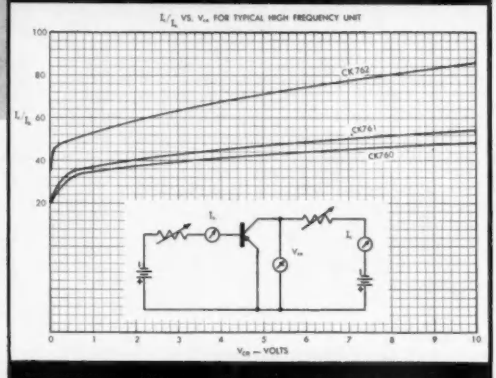

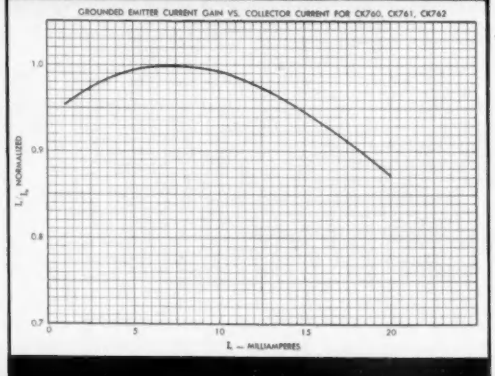

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	Volts	Cutoff μA	mA	Cutoff* μA						
2N112/CK760	−6	1	−1.0	0.5	75	40	5	85	0.62	14
2N113/CK761	−6	1	−1.0	0.5	75	45	10	85	0.62	14
2N114/CK762	−6	1	−1.0	0.5	75	65	20	85	0.62	14

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FEEDBACK

which is growing with great rapidity in the converting areas of organizations such as ours. That control is the automatic registration of one process with another or the registration of multiple operations within a given process such as multi-color printing, punching and laminating. The problem of registration is not peculiar to paper and film converting. It applies to the production of metal foil as well.

The major manufacturers of control equipment, photo-electric and otherwise, are involved in a controversy over fixed rate controls versus rate-proportional and time-proportional controls. Examples of controversial applications are edge-guide systems and circumferential registration systems for large rotogravure printing presses.

An article clarifying the logical selection of the proper types of proportional control should produce a great deal of interest. It would apply to all areas of the control field.

R. B. Lundy
Marathon Corp.
Menasha, Wis.

Two Activated Readers

To the Editor—

We were very interested in the article appearing on page 50 of the March 1955 issue of Control Engineering by J. P. Stewart and G. J. Leighton of Isotope Products, Ltd.

We have a manufacturing problem of controlling moisture in electrical paper on a winding machine. The article indicates that the use of radioactive materials might be a convenient way of measuring the water content.

E. F. Huston
The Ohio Brass Co.
Barberton, Ohio

To the Editor—

In your March, 1955, issue there is an article entitled "Use Radioactive Instruments," written by Messrs. P. J. Stewart and G. W. Leighton of Isotope Products, Ltd. The information contained therein indicates that the density and weight measuring possibilities of this method are applicable to control a phase of our manufacturing.

William F. Quinn
Yonkers, N. Y.

We Aim to Please

To the Editor—

I want you to know that I am very

ON LINE
ON TIME
MEMO
From: Engineering & Production
To: Sales Department
Subject: Size 8 and 22 Synchros
As promised last November, our size 8 and 22 standard synchros are now in production and available for 3 weeks or less delivery.
In addition, we have added the BuOrd type size 15 transmitter to the line.
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1.437" diameter
ACTUAL SIZE
Size 11
1.062" diameter
ACTUAL SIZE
Size 10
.937" diameter
ACTUAL SIZE
BuOrd Size 15
1.437" diameter
ACTUAL SIZE
BONUS
Next
HERE!
TRANSMITTER
TYPE CG-22-A-11
Next
HERE!
Size 8
.750" diameter
ACTUAL SIZE
Size 22
2.161" diameter
ACTUAL SIZE
Look to cppc for Synchro Progress
CLIFTON PRECISION PRODUCTS CO., INC.
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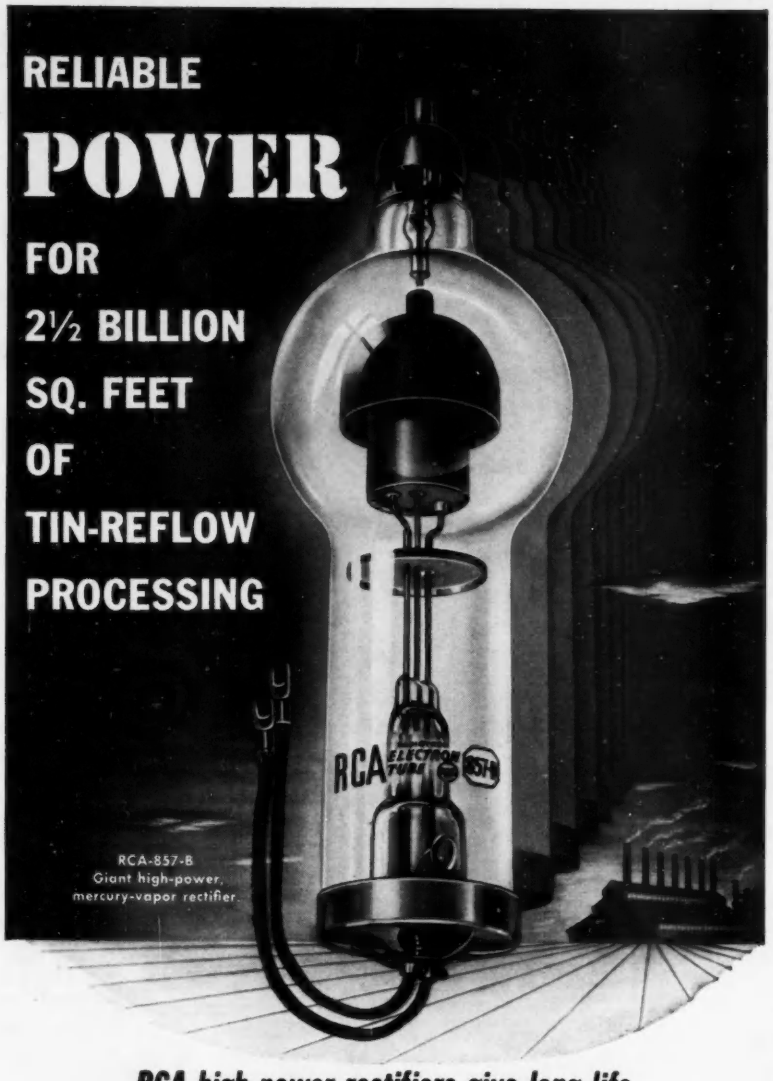

RCA high-power rectifiers give long-life service at Weirton Steel Company—a division of National Steel Corporation

Tin reflow on steel strip, averaging 30" in width, is achieved with amazing speed, quality, and economy at Weirton Steel by means of electronic heating. Moving at the rate of 1,300 ft. or more per minute, the steel strip passes through high frequency heating coils, fed by a group of 200 kw electronic oscillators, which reflow the tin, producing a high quality coating.

To supply the oscillator plate power for this high-speed electronic operation, Weirton uses 24 RCA 857-B's in two banks of 12 tubes each. This rectifier installation has given an average tube life of 12,000 hours...a period representing about 2½ billion square feet of strip production.

Here is another example of the way RCA Tubes are helping industry do a better job at lower cost.

* * *

When you need power tubes, rectifiers, ignitrons, thyratrons, computers, phototubes, or RCA Tubes of any type, call your RCA Tube Distributor. (He's listed in the Thomas' Register.) For tube technical data, write RCA, Commercial Engineering, Section G-56-T 415 S. Fifth Street, Harrison, N. J.

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pleased with the way CONTROL ENGINEERING is put together. It certainly fills a need, and in the short time since it was first issued, it has had quite an influence on my associates and myself.

Specifically, thank you for the non-bookish text, emphasis on "how to", the lucid line drawings, graphs, and tabular material, and last but not least, the freedom from article sermonizing on the great future of automation.

George H. Amber
Detroit, Mich.

Look Up

TO THE EDITOR—

For the sake of trying to see ourselves as others see us, engineers who are deep in the problems of control engineering should lift up their gaze long enough to note the January 22 edition of the *Saturday Review*, an issue devoted entirely to Atoms and Automation in its editorial departments.

I found myself agreeing with little that was written therein, or feeling that the authors had missed the point many times. But then, have a look for yourself, if you did not do so when the magazine was published.

Glen M. Dodd
San Diego, Calif.

An article, "Mechanical Mice," and an editorial, "Time to Think," in opus cite may remind control engineers of their responsibilities to society, but through it all runs a strain of nostalgia for "the good old days" when today's "double-domed robots" were still figments of the imagination.—Ed.

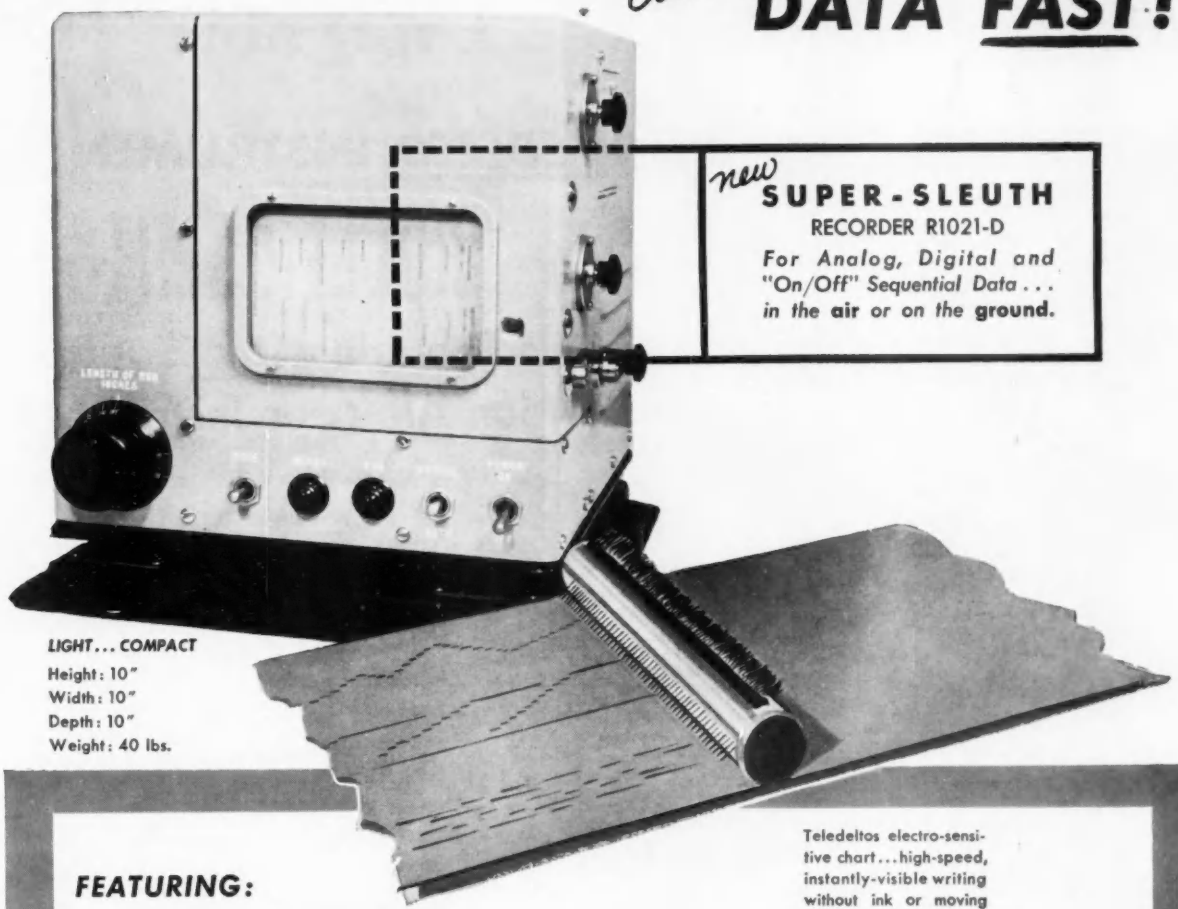
Errata

With our face the hue of our May cover, we note errors in author Takahashi's article, "Graphically Determine the Dynamics of Heat Percolation". Please make these corrections in your file copies:

1. In Figure 1, "heat flow" should read "hot fluid".
2. Delete the equal sign after the comma on the fifth line in the left column of page 48.
3. In the sixth line of the caption for Figure 4, add subscript i to θ_i and θ_i'. And in the seventh line of the caption's right column, add subscript i to θ_i.
4. In the first equation on page 50 add subscript 1 to θ.
5. In equation (c), delete the minus sign ahead of R/L and replace it with an equal sign.

The Editor

A SHORTCUT FOR GETTING *Accurate* DATA FAST!



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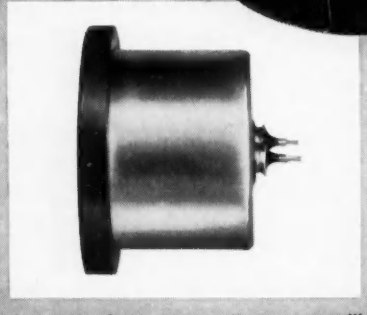

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LOUIS and FRANCES BAUER
ride herd on cyclone

Surely, somewhere some lecturing pundit has said, "Mathematics is the conscience of science."

Twelve years ago a Brown University physics intructor had compelling reasons to test this truism. Officially, of course, his visits to the nearby mathematics department were for guidance in forging a Doctor's thesis in ultrasonics and acoustics. But he also found time for equating a relationship with a charming lady mathematician in the department.

Conscience can become a refreshing habit

Today, as Director of Project Cyclone for Reeves Instrument Corp., Dr. Louis Bauer continues these sensible and refreshing consultations. Breaking away from the static breadboards of his analogs, he strolls to a clicking, whirring, mathematical oasis presided over by that same young lady—now Dr. Frances Bauer, and the "conscience" both for Cyclone and its Director.

Louis Bauer got his Doctorate in June, 1948, and then responded to a Reeves bid to work in its sprouting analog computer project for the Navy. Frances Brand, meanwhile, wrote her thesis in applied mathematics late that summer. But she was Dr. Brand for only two weeks. After the honeymoon Dr. Frances Bauer joined Brooklyn Polytechnic Institute as a research associate in aeronautical structures.

At last, in 1950, Louis Bauer could stop 'phoning Brooklyn for mathematical advice, for Frances came to Reeves as a senior mathematician on the project. But the Bauers had only one year to team up on Cyclone before Louis went to Washington and onto the research staff for the David Taylor Model Basin.

The Bauers team again— and digits join analogs

After a year in Washington Louis Bauer returned to Reeves to head up Cyclone. One of his first sub-projects was to enable Frances to more actively exert her mathematical "conscience". An Elecom digital computer was installed, with Frances at the helm to check on analog programming.

In Project Cyclone a formidable collection of Reeves analog equipment pre-checks the design and performance of guided missiles and aircraft, such as LARK, REGULUS, and CUTLASS. Once a problem is set up, the analogs rapidly produce solutions as conditions are fed in. However, before the problem is run off, Frances Bauer programs its duplicate on the Elecom and compares results with one set of data. Usually there is a remarkable correlation between analog and digital. But if there is variance, the discrepancy is run down before tests begin.

HIS and HERS: Louis Bauer hovers while Frances checks a Cyclone problem. Facing Frances are the panels of her digit-juggling Elecom 100 computer. Not visible, behind Louis, are his silent analogs.

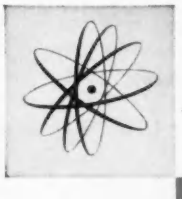
Louis and Frances Bauer maintain a devoted and pleasant vigil over Cyclone. They are inveterate New Yorkers and dote on the colorful river traffic and excellent foreign cookery near their East Side apartment. They are only a short ten minute walk from Cyclone and often stroll in at night or weekends to smooth or speed a project.

Friendly, articulate, and buoyantly young, the Bauers sometimes find it hard to be scientifically impersonal about Cyclone problems. For example, Cyclone's tests predicted a new, carrier-based jet would "stagger into the air", and possibly into the drink. Pronto the pioneer launching was postponed for design changes. Only then did visions of wet and woeful airmen cease to haunt Louis and Frances.

the PRODUCTION ENGINEERING SHOW

SEPTEMBER 6-16, 1955
NAVY PIER, CHICAGO

The Automation Exposition



MONITORING EQUIPMENT
such as: Recording and control equipment. Electronic devices. Switches, relays and electrical components. Counters and computers. Mass spectrometers.

HANDLING EQUIPMENT
such as: Conveyors, Cranes, Hoists, Monorails, Pneumatic tubes. Clamping, rotating and positioning equipment. Loading and unloading equipment.

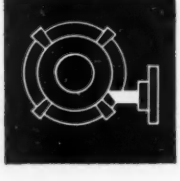
EQUIPMENT COMPONENTS
such as: Air and hydraulic mechanisms. Mechanical activators. Brakes, clutches and other drive mechanisms. Electrical, air and hydraulic motors.

GOVERNING EQUIPMENT
such as: Devices for tramp iron removal. X-ray, fluoroscope and photocell devices. Limit switches and governors.

COMMUNICATIONS EQUIPMENT
such as: 2-way radio. Telephone and paging systems. Teleprinters and facsimile. Industrial television. Special signaling equipment.

INSPECTION AND GAGING EQUIPMENT
such as: Air gages. Strain gages. Beta ray thickness gages. X-ray gages. Optical gaging equipment.

SPECIAL PRODUCTION EQUIPMENT
such as: Continuous heat treating and drying furnaces and ovens. Abrasive blasting and other finishing equipment. Engineered paint systems. Weighing and proportioning equipment.



MACHINE TOOL ACCESSORIES
such as: Bearings, Cutting tools, coolants. Chucks, dies, jigs. Lubrication systems. Portable tools. Power transmission equipment.

An exposition that does something about AUTOMATION. In one place at one time you can *see* the practical things—mechanisms, instruments, controls, handling devices, data processors, hydraulic, electric, mechanical, and pneumatic components—that you can apply *right now* to make your production and processing more automatic.

There's no blue sky about this show. It's been designed for the production function in industry, leveled at the men who must re-engineer production and processing lines *now* to cope with rising costs and hot competition.

There'll be hundreds of exhibits by leading companies. There'll be thousands of technical experts eager to show you how to get more output from your existing plant facilities.

AUTOMATION is here. Today. The things you learn at the Production Engineering Show can go to work for you immediately to cut costs, to improve production performance.

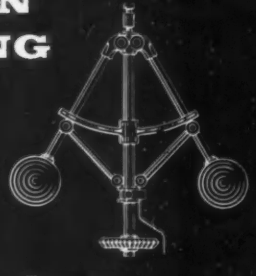
You can see the great MACHINE TOOL SHOW too!

Your registration badge will admit you, at no additional fee, to the world-important Machine Tool Show – the first since 1947 – at the International Amphitheatre, Chicago, concurrent with the Production Engineering Show. Don't miss it! Shuttle buses will run between shows.

See the practical elements of automation that can be applied to your production and processing right now!

PRODUCTION ENGINEERING SHOW

SEPTEMBER 6-16, 1955
NAVY PIER, CHICAGO



The Automation Exposition

Tickets:
To expedite your registration at the Production Engineering Show, write for Rapid Registration Cards to:

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341 Madison Avenue, New York 17, N. Y.

Control Combats Elemental Forces:

FIRE . . . SMOG . . . BEER . . . DATA . . . & . . . DIN

During the past few weeks some routine control events took place at widely scattered points. Individually, at least, they really do look routine. But grouped together they may suggest a trend—or even a movement—to those who dabble in control philosophy. For it appears that our technology has finally transcended dealing with nice hardwarish things and processes. It is now coping with Forces.

What are the Forces? Fire in New England. The air in Southern California. Thirst in Denmark. And confusion and din in New York. How elemental can one get?

In Norwood, Mass., on May 10 a fire was started in a building to demonstrate how feedback could help put it out. This dramatic test was the brainchild of Wasco Products, Inc., of Cambridge, Mass., in cooperation with Factory Mutual Laboratories. It featured Wasco's brand-new fire-control device, "Pyrodome," a fuse-actuated automatic heat vent for the roofs of large open-area buildings.

Although it works on the simplest control principles, the Wasco system made a formidable showing in the test. When heat in the building below fused its link, the plastic dome sprang open to vent off Btu's, smoke, and gases to confine the fire to a small area. In effect, it acted like a self-materializing fireplace.

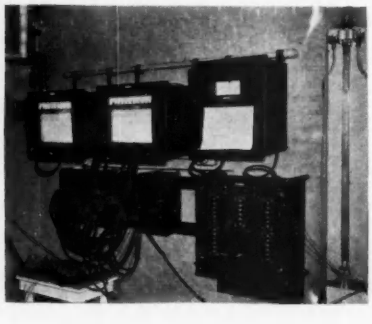
Since its aim was to provide usable data, the test fire was not wild and woolly. Heat was supplied by burning gasoline pumped through a calibrated flow meter to spray nozzles. At 5 gpm, this released an astounding 600,000 Btu per minute—a lot of fire for a 60-by-40-ft plant bay. Air temperatures were measured by thermocouples in, near, and close to the fire. High-speed records were made on two strip charts (see cut).

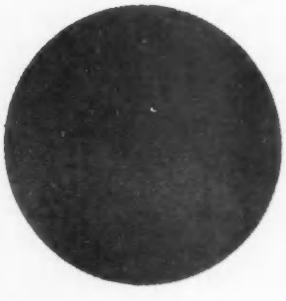
Analysis of test records showed that temperatures dropped sharply as the venting area increased. Thus the fire was not only automatically confined and at the same time attenuated, but was also made more tolerable for infighting firemen. The results were impressive enough to prompt a special report on the system by Factory Mutual. This bulletin is couched in FM's usually cautious style, but positive enough to make it must reading for non-military fire-control engineers.

In Pasadena on April 18 engineers from many U. S. cities converged on the Huntington-Sheraton Hotel to pow-wow on ways to control air pollution. This was the third national meeting on this subject, and two focal points were obvious from paper titles: 1) a specific preoccupation with smog, particularly the Los Angeles brand, and 2) new ways and means to measure this pollution.

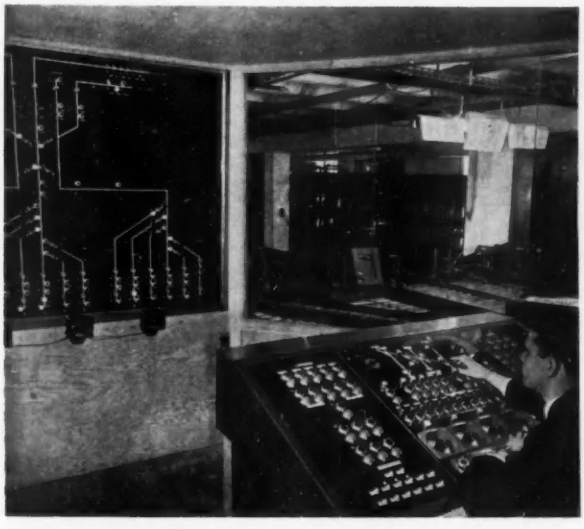
Some of the new measuring tools for smog are intriguing. Dr. Ralph Stair of the National Bureau of Standards is concerned with passage of spectral radiant energy from the sun through the stuff. University of California's Dr. W. D. Hershberger is using microwave techniques to study smog composition. H. W. Patton and J. S. Lewis of Tennessee Eastman believe proper analysis involves gas chromatography. And digital tech-

FIRE CONTROL was dramatized on this Norwood, Mass., rooftop. Heat from below actuated this automatic vent to localize the conflagration below. Test recorders authenticated the results.





SMOG CONTROL seems to be desperately needed in this air view of a prominent western metropolis.



BEER CONTROL for thirsty, unmelancholy Danes occurs through this automatic 2,500 bpm router.

DATA CONTROL was the object of this brisk name-brand equipment act on a New York hotel stage.

niques are being turned on smog by Armour Research Foundation, Indiana University, and Johns Hopkins.

Some possible conclusions from this meeting: The stage has been reached where *what has to be measured* is known. Now the problem in the works is *how to measure it*. And, perhaps, in three or four years *how to control smog* will be achieved through some kind of feedbock system. As Doc Mason might say, "It's inevitable."

In Copenhagen an efficient control system will help slake the thirst of one million Danes this sunny Scandanavian summer. Well, beer-drinking Danes, anyway. The system: a very fancy, flexible, automatic bottle-routing operation made by Alvey Ferguson Co. of Cincinnati, and installed in Copenhagen's Tuborg brewery. The results: very little time between "skols," since 150,000 bottles per hour now automatically pour from the brewery via fast city delivery trucks into thirsty Danish throats.

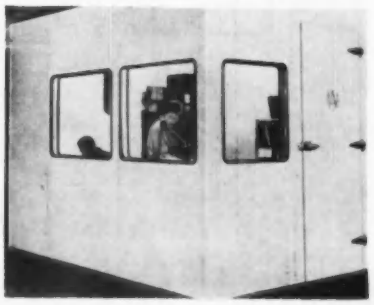
Two Ferguson control systems—one for outgoing beer, one for returned empties—do the job through a central graphic panel under one operator. Photocells along incoming and outgoing conveyor belts pick up and signal movements. The operator watches his lights on the graphic panel and pushes buttons to switch remote-controlled routing tracks. Photocell impulses also count outgoing cases and automatically dispatch a desired number to each waiting truck. Trucks move through the plant like pastries through a Danish kitchen. As the driver unloads his empties, his order goes by pneumatic tube to the office, where it is processed. A copy of the order goes to the control room. Unloaded, he drives an assigned truck onto the loading platform. The control room dials the number of items, which are automatically served in from various areas, and starts track-feeding the waiting truck at 50 cases per minute. Since the track—from switchyard to loading dock—holds one full truckload of cases, the driver can start and stop his delivery conveyor at the necessary point.

In New York City on May 11 five hundred executives slipped away from deskjams of paper to jam themselves into the Hotel Biltmore's Music Room for a practical pitch on how to control paperwork. Their host, Standard Register Co. of Dayton, Ohio, put on a good show. Since it makes the paper forms for data-processing and not the equipment, it could take a broad, across-the-equipment-board view. Hence its talk and working-platform demonstration focused on twelve different makes of hardware and their use in an integrated system.

Here is the lineup of components that Standard Register put through paces using omnipresent S. R. forms: Addressograph's Automatic Graphotype; Bell Systems' automatic sending and receiving teletypewriters; Commercial Control's Flexowriter; Friden's Add Punch; IBM's tape-to-card converter; Remington Rand's tape-to-card converter; Underwood's tape-to-card converter and Electronic Code Writer; Victor's digital printers; Visi-record's tape storage element; Western Union's teleprinter and reperforator; Wheeldex's tape storage element. How this field and its hardware are growing!

While the fascinating click and clack of data-processing equipment seem to draw comptrollers and office managers like flies, there are some engineers who function inversely with din. Hence the "Quiet Room," or packaged noise control. The "Quiet Room" made by Industrial Acoustics Co., New York, is a prefabricated room with high noise reduction in all frequency bands. It comes in six sizes and can be set up wherever those hypersensitive to hubbub work. Assuming what can't get in, can't get out, this dinless box might also make a functional play-house for Junior.

AND DIN can be controlled—or obfuscated—by this soundproof box for introverted engineers.



INSTITUTIONAL DOINGS

Academically speaking, control has no summer slump. In fact, this is the time of year when many control engineers in industry can go back to ivy halls for that needed refresher. Some of the incentives:

Purdue—A three-day conference on Systems Engineering is planned for July 25-27. Some of the lecturers: Control Engineering's Bill Vannah, on control evolution; Donald McDonald of Cook Research Lab and J. M. Harrer of Argonne, on servo theory and application; J. G. Truxal of Brooklyn Polytechnic, on network theory and its application to process control; J. R. Clark of Purdue, on analog computers in control; and J. R. Ragazzini of Columbia U., on the effect of noise in control.

Wisconsin—An eight-week summer session in Advanced Servomechanisms and Automatic Control Theory starts June 27. Professor T. J. Higgins will conduct the course. Write him for the outline and you'll see a truly comprehensive, beautifully organized approach to the subject. It's an ambitious program for eight weeks and a tremendous value for the modest $70 fee.

M.I.T.—This Cambridge institution continues as a hotbed of automatic control despite lures of summer boating on the Charles. Three of the special courses: Survey of Numerical Analysis Principles and Techniques, June 20-July 1; Noise in Electronic Devices, July 18-29; and Fundamentals and Applications of Strain Gage Techniques, July 25-August 5.

DATA PROCESSING HITS THE ROAD for the Benson-Lehner Corp. in this $100,000 equipment-packed 40-ft coach. Youthful President Bernard Benson, sitting up front, predicts a big sales boost.

COMPUTER ROUNDUP

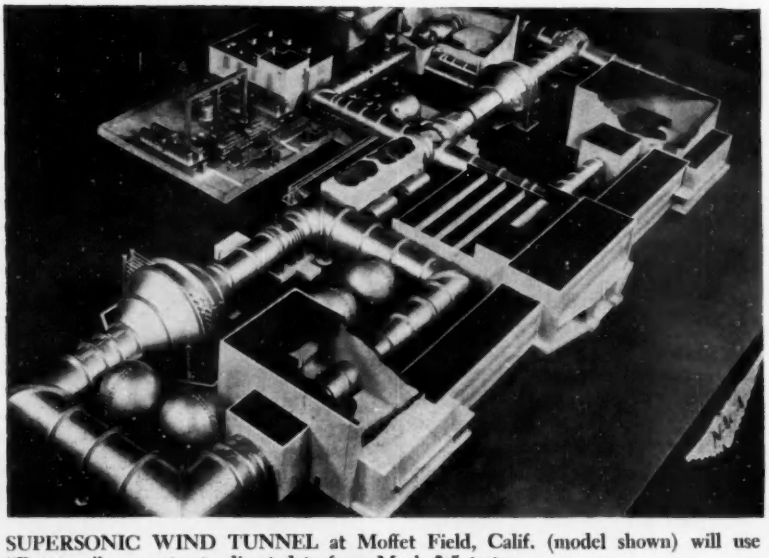
IRS Takes a Hunk of Univac

The Internal Revenue Bureau is overtaxed. A lesser-known part of its job is to statistically analyze incoming data on its 85 million "clients". This yearly 500-page report is now three years behind. So IRS has latched onto a quarter-interest in the Census Bureau's Univac to help get out from under. To do its job, IRS has also secured the world's first punchcard-to-Univac tape converter and a 600-lines-per-min printer. Eventual Bureau objective: to feed Univac tax info directly by teletype from branch offices and do away with punchcards entirely.

MIRACLE Bails Out Dutch

The Amsterdam Laboratory of the Royal Dutch Shell group of oil companies is now solving its product and process calculations with MIRACLE, a $450,000 electronic computer. Built by Ferranti, Ltd., of Manchester, England, its name is a contraction of Mokum's Industrial Research Automatic Calculator for Laboratory and Engineering. "Mokum" is a colloquialism for Amsterdam.

MIRACLE has capabilities to match its name and cost. It will multiply 12-figure numbers in one second and perform 32 separate operations. It employs both a magnetic drum and TV tube memories and can store about 16,000 arbitrary numbers of 12 figures.



SUPERSONIC WIND TUNNEL at Moffet Field, Calif. (model shown) will use a "Datatron" computer to digest data from Mach 3.5 tests.

Pipeline Deliveries Digitized

In proudly announcing its tenth anniversary, Midwest Research Insti-

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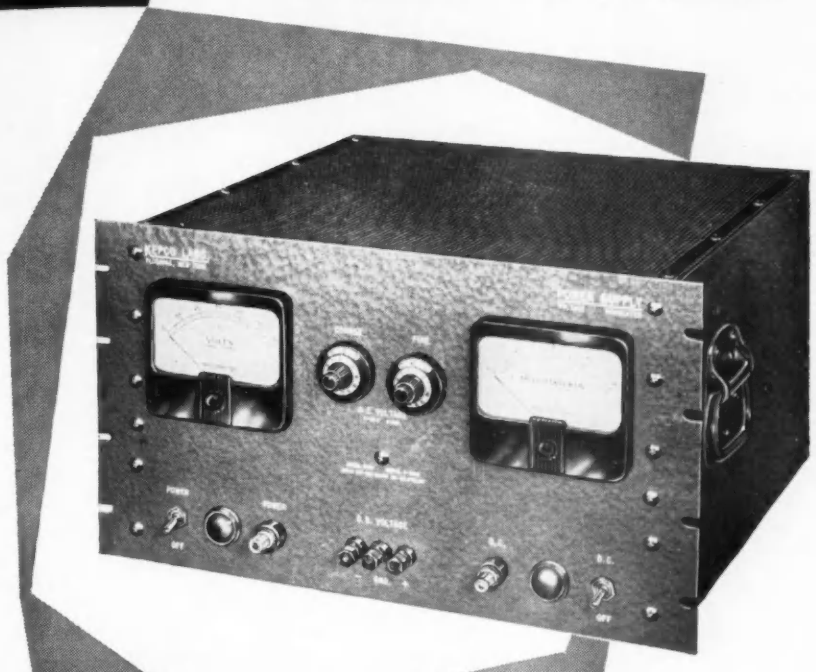
Presents 2 New VOLTAGE REGULATED POWER SUPPLIES

KEPCO Voltage Regulated Power Supplies are conservatively rated. The regulation specified for each unit is available under all line and load conditions within the range of the instrument.

REGULATION: As shown in table for line fluctuations from 105-125 volts and load variations from minimum to maximum current.

SPECIAL FEATURE: Provision is made for picking up the error signal directly at the load, compensating for the voltage drop in external wiring.



Model 2600

OUTPUT	VOLTS	CURRENT	REGULATION	RIPPLE
1	0-60	0-2 Amp.	5 Mv.	1 Mv.

Model 2650

OUTPUT	VOLTS	CURRENT	REGULATION	RIPPLE
1	0-60	0-5 Amp.	5 Mv.	1 Mv.

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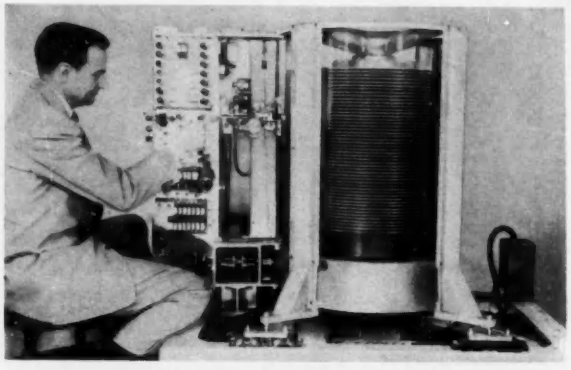
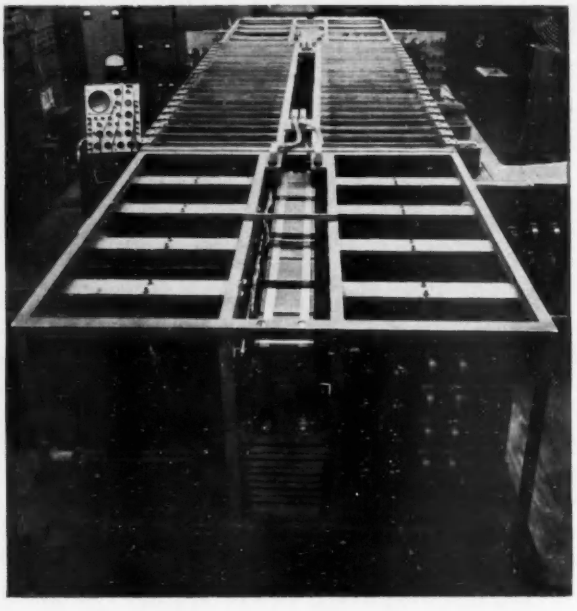




NEW MEMORIES are blossoming out to best one of the drags on high speed computing. IBM's above is a magnetic disc for quick access to 5 million characters. International Telemeter's, right, also magnetic, is said to be world's largest and will grasp a 40-digit number in 0.000.015 sec.

tute let a fascinating cat out of its bulging computational bag. It revealed the completion of a research project in applying data-processing to fluid-carrying pipeline network terminals. Mathematical analysis involving queuing theory and Monte Carlo methods showed that waiting time at the truck-loading facilities could be reduced appreciably. The Institute's digital computers and its McIllroy pipeline network analyzer were used in the calculations. As Midwest puts it, the results are "the first step towards automation of the terminal delivery system". Too bad we couldn't have tacked this technique onto the Pipeline Telemetering feature article in this issue (see p. 48).

Next: Colorful Computation

Oh, how those fertile imaginations worked overtime! We refer to RCA's recent unveiling of its prototype system for storing color television and transmitting it from a magnetic tape developed by Minnesota Mining & Manufacturing Co. Imagine comparing Miss America 1975 against the stored memory of previous curves—in color, yet! Or, more stodgily, working out a continuous pictorial feedback system for quality control of industrial products for color, dimension, and even dynamic motion. The actual demonstration that spurred these fancies was a color tape transmission from New York to St. Paul of a program featuring General Sarnoff, Bambi Lynn and Eddie Fisher. They talked, sang, and danced their way off the tape with aplomb.

Important Moves by Key People

▶ **Harold R. Nelson,** general supervisor of electrical engineering at Geneva Works of United States Steel since 1951, has been appointed chief research engineer in the Research & Technology Div. He will concentrate on automatic controls, instrumentation, and mechanization.

Glyn A. Neff is the new project engineer for data processing systems of Consolidated Engineering. Neff, who helped develop Consolidated's MilliSADIC, now turns his attention to atomic reactors, jet engines, and guided missiles.

▶ **John A. Wiedmann** has joined A. W. Cash Co. as director of research. He has been with Minneapolis-Honeywell and Schutte & Koerting Co.

▶ Vice-president **James F. Magin** of Square D Co. has been appointed general manager of the Industrial Controller Div.

▶ **John W. Brubaker** and **Edward C. Light** take on new duties at Summers Gyroscope: Brubaker, formerly chief engineer, becomes vice-president, engineering, and Light returns to the company as engineering assistant to the president.

▶ **John M. Wilson** is the new chief engineer of the Development & Design Div. of the Engineering Dept. of Minneapolis-Honeywell's Brown Instrument Div. He has been chief electrical engineer of Honeywell in Minneapolis.

▶ **William M. Pease,** the new vice-president and general manager of Feedback Controls, Inc., has been vice-president and general manager of the Electronics Div. of Ultrasonics. Before that, as director of the Servo-

U. S. Steel's Nelson

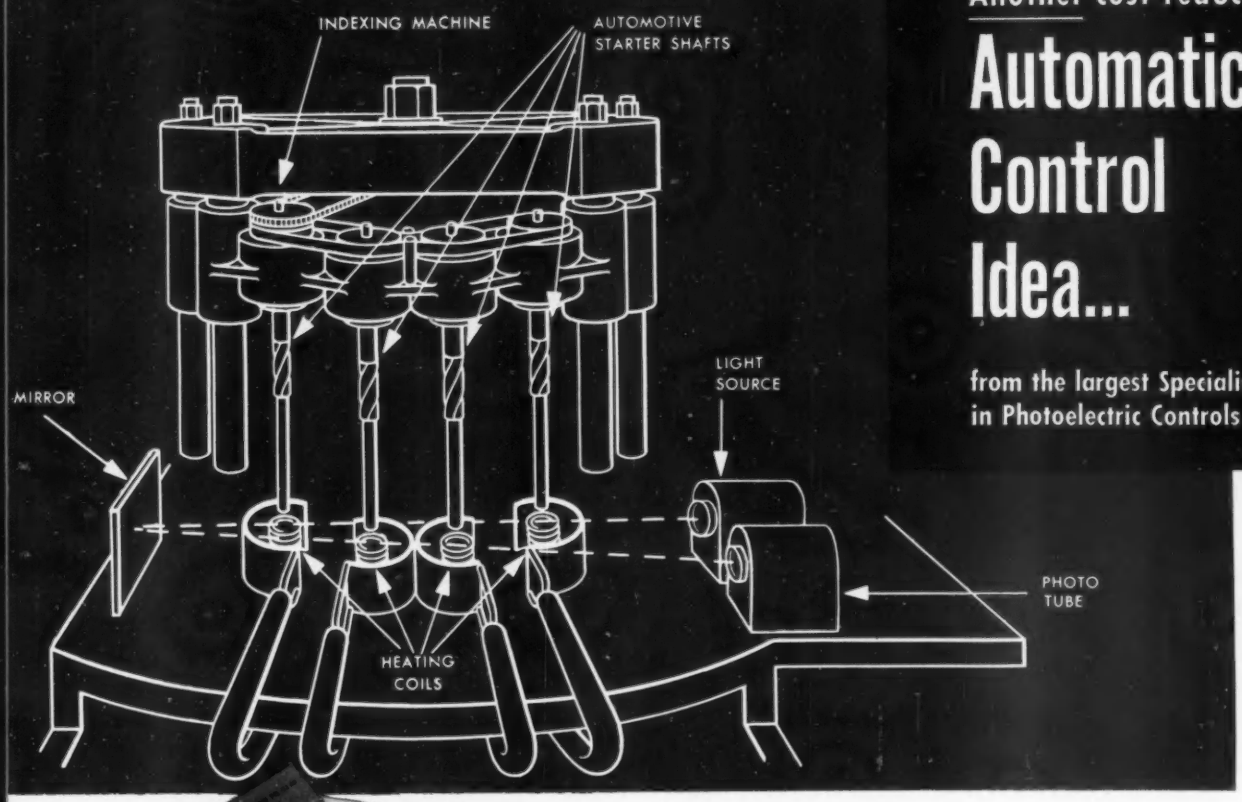
Con. Engineering's Neff

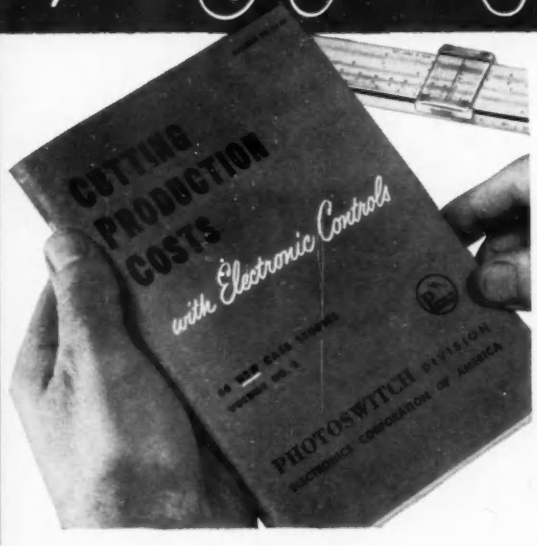
A. W. Cash's Wiedmann

Another cost-reducing

Automatic Control Idea...

from the largest Specialists in Photoelectric Controls





FREE— 45 more ideas — Get this 76-page book. Shows in detail how designers of machines for many different industries have employed standard packaged electronic controls. Tells how they found new opportunities to reduce costs through simplification of design . . . how they developed order-getting user advantages. Shows you how easy it is to apply Photoswitch Controls for sorting, counting, starting, stopping, inspecting, indexing, adjusting, weighing, timing, limiting, safeguarding, etc.

SEND FOR YOUR COPY NOW ▶

Precise Timing and Machine Protection in High-Speed Automatic Hardening Operation

Problem: To ensure precise quality control while hardening automotive starter shafts in a special indexing machine. Also to prevent damage to equipment caused by indexing before shafts have cleared heating coils.

Solution: Induction Heating Corporation in designing this special automatic hardening machine utilized a Photoswitch Photoelectric Control Set and 4 Photoswitch Electronic Timers. The shafts are automatically indexed over the heating coils, then lowered into position. The unit hardens two zones of each shaft simultaneously . . . an operation requiring greater accuracy than necessary for ordinary heat timing operations. The Photoswitch Timers precisely regulate the critical periods of initial heat time, hold time, quench time and draw heat time. The shafts are then withdrawn and the Photoelectric Control scans between the bottom of the shafts and the top of the coils to ensure that all shafts are fully removed before fixture can index. It is estimated that to replace one damaged heating coil would cost more than the initial cost of this foolproof photoelectric machinery safeguard.

Result: Precise quality control achieved through automatic timing — 1400 hardened starter shafts per hour are produced. Damage to heating coils completely eliminated.

In Photoswitch's wide variety of "ready-to-use" photoelectric controls, liquid level controls, and timers, you will find controls that precisely meet your requirements. So . . . for the best solution to your control problems, remember the name, *Photoswitch*.

Photoswitch DIVISION
ELECTRONICS CORPORATION OF AMERICA
Dept. P27-7, 77 Broadway, Cambridge 42, Mass.

Send FREE copy of "Cutting Production Costs with Electronic Controls."

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Company.....

Address.....

City..... **State**.....

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PHOTOCONDUCTOR-TRANSISTOR DIVISION • MARINE DIVISION • MILITARY DIVISION

mechanism Laboratory of M.I.T., he assisted in the birth of the institute's numerically controlled milling machine.

▶ As the new chief electronics control engineer in the Engineering & Production Div. of Airborne Instrument Laboratory, **Lawrence J. Torn** will coordinate production design of industrial control systems.

▶ **John J. Dempsey,** named manager of the Components Div. of Servomechanisms, Inc., has been chief development engineer in the Eastern Div. since 1951.

▶ **Roy Schoenhaar,** project supervisor in the Engineering Div. of Ford Instrument Co. since 1951, has been appointed assistant chief draftsman.

▶ Ampex Corp.'s appointment of **Harold V. Childs** as manager of the Field Service Engineering Dept. puts him in charge of field service programs of the Audio and Instrumentation Divs.

▶ **Milo L. Voight,** formerly controller of the Milford, Conn., operations of Norden-Ketay, has taken over as controller of the whole corporation.

▶ Helipot has named **Dawson Teaford,** regional sales manager, liaison man between the corporation and the architects who are designing Helipot's new $2 million main plant in Newport Beach, Calif.

▶ Perkin-Elmer has elected **John M. S. Hutchinson** vice-president and assistant to the president. Hutchinson was instrumental in Chrysler's atomic energy project.

▶ New engineering manager of Lear's Grand Rapids Div. is **T. K. Greenlee,** formerly chief electro-mechanical engineer of the division.

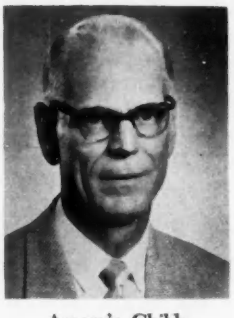
▶ **Ralph L. Bayless,** now chief engineer of Convair-San Diego, has been assistant chief engineer in the research, development, and technical sections. Bayless, who succeeds **F. W. Fink,** has had other important Convair titles: chief of aerodynamics and chief development engineer.

Feedback Control's Pease

Airborne's Torn

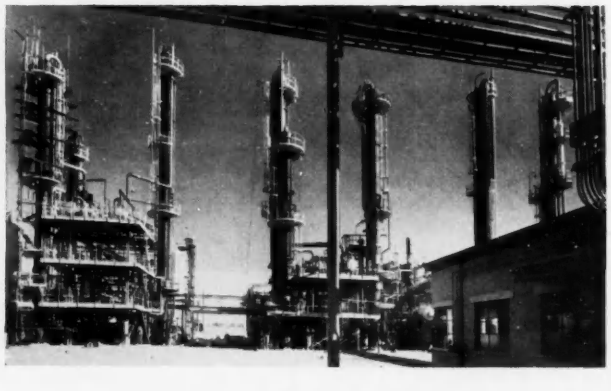
Servomechanisms' Dempsey

Ford's Schoenhaar



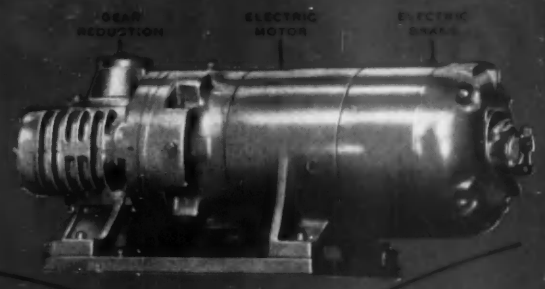
Ampex's Childs

Helipot's Teaford



Control station centered like orchestra podium for conducting new Hercules oxychemical plant

Here is how Hercules Powder Co. circumvented the need for a graphic control panel at its new Gibbstown, N. J., oxychemical plant. The control room (lower right corner of picture at left) is located inside a "U" formed by the complete outdoor process. And its panel instruments are placed in a corresponding arc inside. Hence, the operator can simply swivel to gaze out a picture window at the associated process unit.

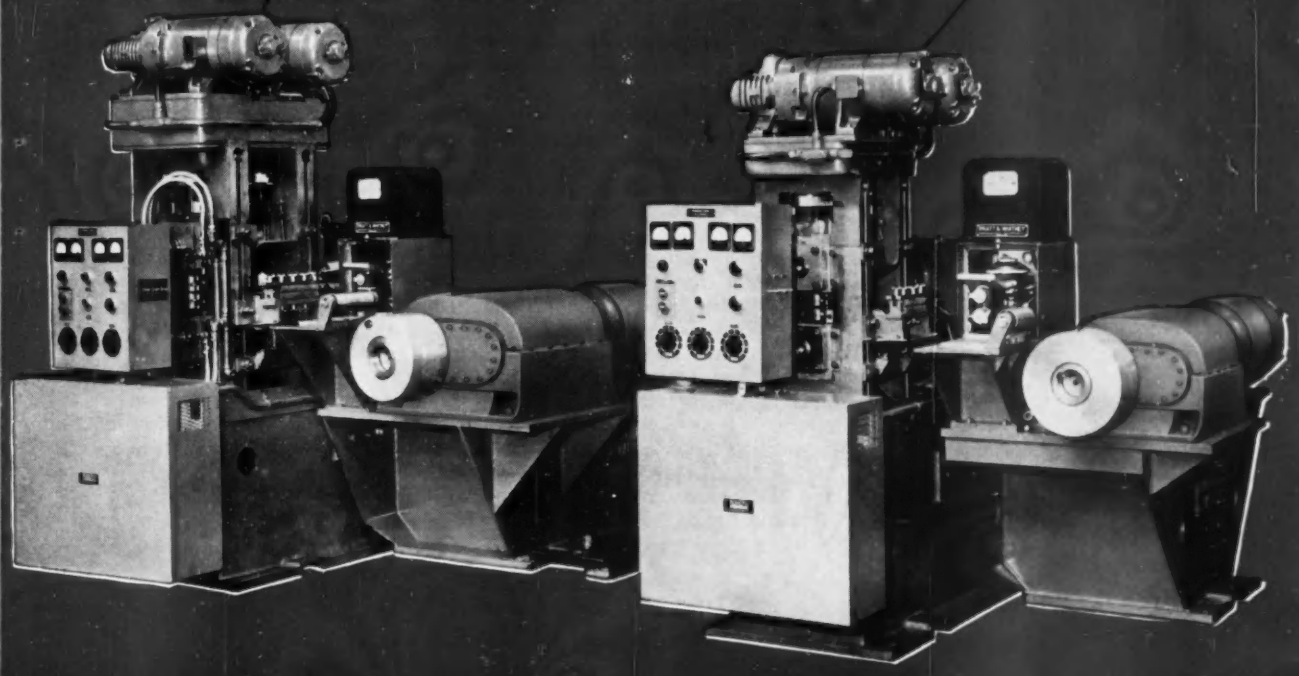


See how easily the standard electric motor, standard gear reduction, standard electric brake combine into a drive that gives the RIGHT horsepower, the RIGHT shaft speed, the RIGHT features . . . all in one compact unit. Nowhere else will you find power units that are so flexible, so easily adaptable, and in such a wide range of types and ratings.

Master power drives are available in thousands and thousands of ratings (⅛ to 400 HP) . . . in open, enclosed, splash proof, fan cooled, explosion proof . . . horizontal or vertical . . . for all phases, voltages and frequencies . . . in single speed, multi-speed and variable speed types . . . with or without flanges or other special features . . . with 5 types of gear reduction up to 430 to 1 ratio . . . with electric brakes . . . with fluid-drive . . . with mechanical or electronic variable speed units . . . and for every type of mounting . . . Master has them all and so can be completely impartial in helping you select the one best power drive for you.

standard units easily combine into special purpose drives

THE MASTER ELECTRIC COMPANY • DAYTON 1, OHIO



Do you think about Angular Acceleration?

BOEING does!

...and uses Statham Angular Accelerometers to test...

Statham unbonded strain gage liquid rotor angular accelerometers offer a simple, reliable means for the study of the rotary motion of a test body under conditions where a fixed mechanical reference is not available. For static and dynamic measurements in ranges from ±1.5 to ±3,000 rad/sec², four standard models are offered.

Please request Bulletin AA2

Statham

LABORATORIES

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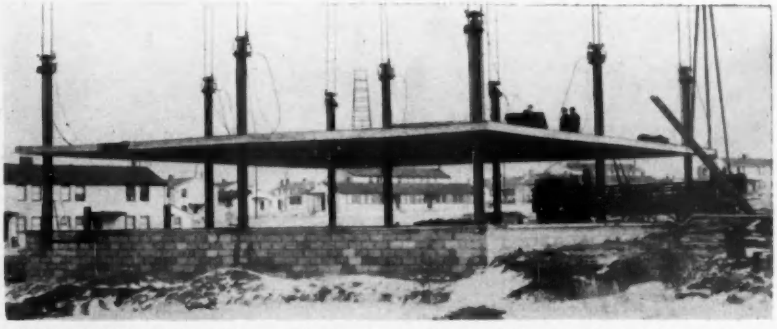
WHAT'S NEW



ON THE WAY UP is this new fluid meter calibration laboratory for Fischer & Porter in Hatboro, Pa. Note the tricky new construction method. The concrete roof is poured on the floor, then raised.

ALREADY UP is this handsome new Raytheon Manufacturing Co. warehouse and sales office in a Chicago suburb. It has 30,000 sq ft of floor space.

Around the Business Loop

▶ Shareholders of **Remington Rand, Inc.**, and **Sperry Corp.** walked out of a meeting May 26 under a new banner: **Sperry Rand Corp.** Standard bearers for the new corporation, which had to pass muster by at least two thirds of the shareholders of each company, are Gen. Douglas MacArthur, chairman, and Harry F. Vickers, president and chief executive officer. Vickers has been president of Sperry Corp.

The meeting consummated a marriage that had been the talk of the control field since the engagement about two months ago. Combined assets of the two companies are expected to total about $484 million. Other new officers: James H. Rand, vice-chairman; John H. Sanderson, vice-president and secretary, and Bernard O. Reuther, vice-president and treasurer.

At the meeting the two companies took, through their proxy statements, a first step: they announced that they will recommend to the new board an initial quarterly dividend of 16 cents per share to be paid on the new common stock.

Recently CONTROL ENGINEERING referred to Sperry Corp. twice—and both times incorrectly. (See What's New, May, 1955.) This consistency at least proves good intentions, and it is hoped that Sperry Corp., before it surrenders its identity, will accept apologies.

▶ As General Electric unveiled the home of its Specialty Control Dept. in Waynesboro, Va., the department's sister, Industry Control, was getting ready to move into its own new Virginia plant, near Salem. Expected time: early in 1956. Both departments are arms of the company's Switchgear & Control Div.

Dr. L. T. Rader is general manager of the new Waynesboro plant, a 19,000 sq ft structure, which, with its Salem counterpart, hopes to manufacture enough electronic control equipment to meet a soaring demand. According to Dr. Rader, this demand will double in five years and triple by 1965. GE calls its Waynesboro installation the largest ever built for its specific purpose.

▶ **Magnasync Mfg. Co.** is organizing a new division, **Automation Corp. of**

Over the twelve years that Fairchild has been making precision potentiometers — from our first unit (Type 736), on through the more than eighteen different types now in production — we have established and are carrying out a research and development program on new designs and materials, techniques and equipment that is constantly improving our potentiometer reliability. The results of this program are quickly applied to production units and these improved methods and designs are maintained by comprehensive quality control and type testing programs.

MAXIMUM RELIABILITY...

how do you get it?

Reliability in precision potentiometers resolves itself into three basic factors; longer shelf life, longer rotational life, and longer environmental life. Fairchild has increased the average shelf and rotational life expectancy of precision potentiometers far beyond usually expected life cycles, in one way, by compounding and using special potentiometer lubricants. Life expectancy and stability under abnormal operating conditions have been vastly increased through the use of precision-machined aluminum alloy case construction. Epoxy resin insulation, one-piece Paliney conductive springs and contacts, and precious metal alloy resistance elements, for certain applications, also contribute to increased life and functional reliability. Whether one or all of these factors of reliability are important to you, you'll do better to choose Fairchild Precision Potentiometers. For specific facts, write Fairchild Camera and Instrument Corporation, Potentiometer Division, 225 Park Avenue, Hicksville, Long Island, New York, Department 140-64C1.

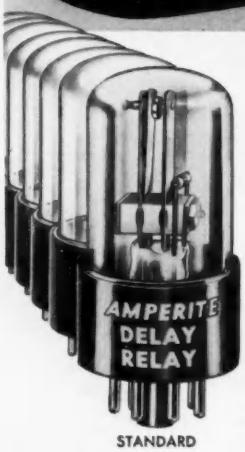
FAIRCHILD
PRECISION POTENTIOMETERS

More Engineers on A-N and civilian projects are proving—

It pays to specify

AMPERITE
DELAY RELAYS
and
BALLAST REGULATORS

...they're finest *...cost less!*



STANDARD

Thermostatic DELAY RELAYS

MOST COMPACT, HERMETICALLY SEALED

Provide delays ranging from 2 to 150 seconds.

- Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.
- *Hermetically sealed.* Not affected by altitude, moisture, or other climate changes.
- Circuits: *SPST only* — normally open or normally closed.

Amperite Thermostatic Delay Relays are compensated for ambient temperature changes from —55° to +70°C. Heaters consume approximately 2 W. and may be operated continuously. The units are *most compact, rugged, explosion-proof, long-lived,* and — *inexpensive!*

MINIATURE

TYPES: Standard Radio Octal, and 9-Pin Miniature.

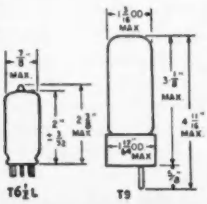
PROBLEM? Send for Bulletin No. TR-81

Also — a new line of **Amperite Differential Relays** — may be used for *automatic overload, over-voltage, under-voltage* or *under-current protection.*

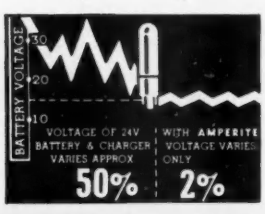
T9 BULB

BALLAST REGULATORS

- Amperite Regulators are designed to keep the current in a circuit ***automatically regulated*** at a definite value (for example, 0.5 amp).
- For currents of 60 ma. to 5 amps. *Operates on A.C., D.C., Pulsating Current.*
- Hermetically sealed, light, compact, and most inexpensive.


T6½L T9

Amperite Regulators are the simplest, most effective method for obtaining ***automatic regulation*** of current or voltage. ***Hermetically sealed,*** they are not affected by changes in altitude, ambient temperature (—55° to +90°C), or humidity. Rugged; no moving parts; changed as easily as a radio tube.



Write for 4-page Technical Bulletin No. AB-51

AMPERITE CO. Inc., 561 Broadway, New York 12, N. Y.

In Canada: Atlas Radio Corp., Ltd., 560 King St. W., Toronto 2B

WHAT'S NEW

Henry F. Dever, new SAMA president, gets the gavel from outgoing Edward J. Albert. Dever is also President of Honeywell's Brown Instrument Div. and Albert heads up Thwing-Albert Instrument Co.—both of Philadelphia.

America, which will produce equipment for controlling milling machines and lathes by magnetic tape. A small manufacturing plant with 10 milling machines could be doctored for control for less than $100,000, according to Magnasync's president, J. D. White.

▶ **Norden-Ketay** has channeled its manufacturing functions into two new divisions. General manager of the **Precision Components Div.,** New York and California, is Robert F. Carleton. Its specialty: precision servomechanisms and other electronic components. Ernest J. Greenwood, Jr., is general manager of the **Instrument & Systems Div.,** Milford, Conn. Its specialty: precision instruments and automatic control systems.

The **Norden Laboratories Div.,** White Plains, N. Y., under Executive Director L. T. E. Thompson, will continue research and development as a separate section. The realignment, according to President Morris F. Ketay, "lends itself to future growth with minimum disturbing effect on current profitable production."

▶ The **Giannini DATEX Div.,** a new arm of the company's **Laboratory Apparatus Div.,** will pitch into the LA division's backlog of orders for digital data handling systems.

▶ **Robertshaw-Fulton Controls Co.'s American Thermometer Div.** now is **American Controls Div.**

Among recent or proposed acquisitions:

▶ **Advance Electric & Relay Co.** by **Elgin National Watch Co.** This is the third manufacturer of miniature electronic components to be acquired by Elgin, others being **Neomatic, Inc.,**

and **American Microphone Co.** President Fred W. Falck, Jr., and other top officers will remain temporarily with Advance, which will be directed by A. P. Barton, general manager of Elgin Neomatic.

▶ **Ahrendt Instrument Co.** by **Litton Industries.** Ahrendt's president, William Ahrendt, will become an executive of Litton.

▶ **Todd Co.** by **Burroughs Corp.** (proposed). Todd would become a subsidiary of Burroughs and its president, George L. Todd, and other officers and personnel would remain with the company.

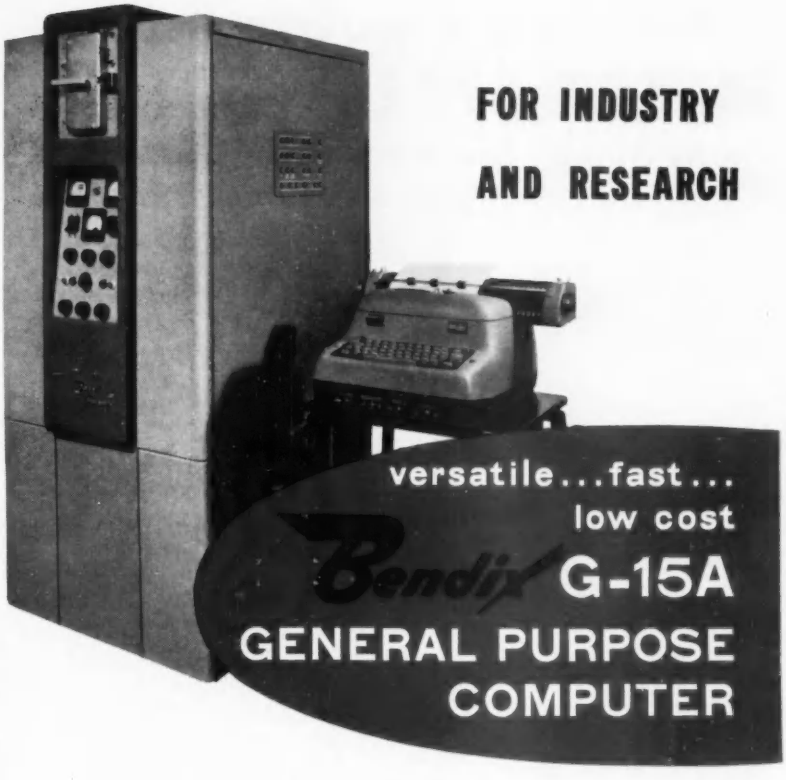
Additional emphasis on control equipment and systems designs are reflected in the annual (1954) statements of three companies:

▶ Though much of its work is classified, **Lear, Inc.,** can report a spurt of military interest in its gyros, flight controls, fuel control valves for special fuels, fast response servos, etc. Many of these components are being included in advanced missile developments and weapons systems, indicating quantity production soon. Lear's dollar volume of sales has increased despite reduced selling prices per unit. Total sales were $54,220,637, up $3,386,727 or 6.6 per cent over 1953. Net earnings totaled $2,202,727, an increase of $939,354. Backlogs amounted to $45.7 million at the end of the first quarter of this year.

▶ Established by **Consolidated Engineering Corp.** during 1954 were its new electronic computer affiliate, ElectroData Corp., and a Systems Engineering Div. for instrumentation and process control equipment. The latter is part of a five-year booster program for technical advancement, sales, and net profits. During 1954, the company's best year, sales totaled $15,644,520.

▶ **General Controls Co.,** which is shooting for a top spot in the appliance controls field in 1955, points to its new central control panel, said to simplify installation problems. During 1954 it put into action a diversification program that is expected to put production and sales on a more even, year-round keel. Sales volume, $19,052,577, was at an all-time high.

▶ **Consolidated Avionics Corp.,** a new subsidiary of **Consolidated Diesel Electric Corp.,** will develop and manufacture servos, digital data reduction equipment, and electronic instrumentation. President is Harry R. Glixon, formerly of **Servo Corp. of America.**



The G-15A is a stored program digital computer which performs arithmetic and logical operations at high speed. It incorporates an improved two-address command structure which permits greatly increased flexibility.

The machine is convenient to operate, with all controls centrally located on the electric typewriter. It can be programmed to solve all classes of mathematical problems. The Computer will operate using single or double precision numbers. In addition efficient floating point performance is possible through the use of sub-routines.

The Bendix is one of the lowest priced general purpose computers available. The machine is in production.

The G-15A is unusually compact because of its advanced logical design and occupies only as much space as two filing cabinets.

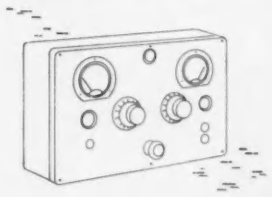
MAIL THE COUPON TODAY
OR WRITE FOR COMPLETE INFORMATION

Bendix Computer

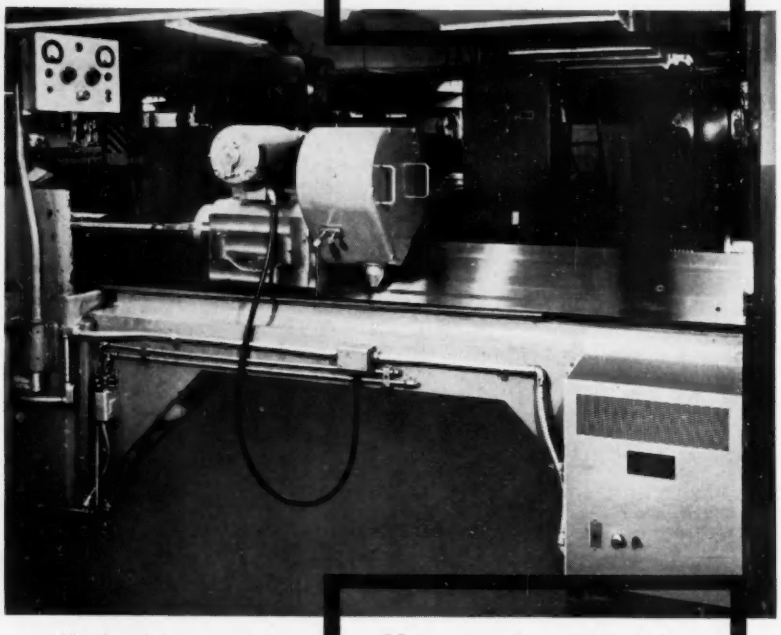
BENDIX COMPUTER DIVISION • 5630 ARBOR VITAE STREET, LOS ANGELES 45, CALIF.
Please send information and prices on your G-15A Computers.
NAME_____ TITLE_____
COMPANY_____ ADDRESS_____

EXPORT DIVISION: BENDIX INTERNATIONAL, 205 EAST 42nd STREET, NEW YORK, N.Y.

having trouble with MOTOR SPEED CONTROL? -write Dressen-Barnes



If you're not getting the precision control you require, or you can't make a system work, write us your problem. We'll design exactly what you need. Dressen-Barnes fabricates electronic motor controls that make operations automatic on machine tools, or in any system with measurable physical factors such as differences in temperature, pressure, electrical conductivity or fluid flow. We design simple or complex controls . . . for programming, sequencing or proportioning — controls for use on existing equipment. Illustration shows a typical example.



db designs motor speed controls for:

- fractional to 50 hp DC drives
- adjustable or proportional speed—continuously variable
- single or multiple pre-selected speeds
- single or multiple locations

send us your problems

The solution may be simple to our experienced staff. We'll quote on a design guaranteed to work. By calling us, you stand to save hours of shopping around and experimenting. Write today.

db speed control for precision thread grinder

Problem here was to get rid of a vibration in the feed motor . . . to increase its reversing speed, and provide continuously variable speed with a regulation of 1%. The vibration was caused by a pulsing DC input current. Dressen-Barnes solved this one by installing a controlled rectifier with output filtered to supply smooth DC. Using this rectifier and a standard DC motor, Dressen-Barnes met all other requirement including separate speed controls for forward and reverse . . . controlled acceleration, braking, and a speed range of 20 to 1.

dressen-barnes

DRESSEN-BARNES CORP., 250 N. Vinedo Ave., Pasadena 8, Calif.

Manufacturers of: Regulated Voltage Power Supplies • Regulated Current Power Supplies
Motor Speed Controls • Generator Voltage Regulators • Magnetic Amplifier Control Devices

WHAT'S NEW

Wiener Reveals More About Brain "Clock"

On a snowy night last February, guest-speaking in a restaurant jammed with M.I.T. alumni, Norbert Wiener permitted a tantalizing peek into a phase of his academic activities (see CONTROL ENGINEERING, Feb., 1955, p. 50). His informal disclosure: He and his colleagues had discovered in the human brain a "clocklike" mechanism that may account for unity in complicated thought-action.

Four months later an English audience was treated to the full story. On June 2 at the University of Southampton, Dr. Wiener described brain wave analysis tests at Massachusetts General Hospital by Dr. John Barlow of the hospital, and Robert Brown of the Institute's Research Laboratory of Electronics. An analog correlator (a special analog computer developed by Barlow and Brown) takes tape-recorded brain waves, processes them, and prints a graph showing the continuity of the signals.

According to Dr. Wiener, the new machine, in sorting random brain pulse activity, disclosed rhythms that described "an accurate clock in the brain of man—a clock of good consistency, beating about 10 times per second, and keeping phase with itself for perhaps hundreds of seconds."

"Clocking is both a useful and recognized phenomenom in many mechanical control mechanisms," Dr. Wiener continued, "and it seems likely to be equally essential in the control machine of the brain."

How Stable Are Brain Waves?

These experiments represent the first systematic analysis of the electrical activity of the brain. When completed, they will make it easier to answer such questions as: "How stable a phenomena are brain waves?" and "If a range of normal stability for brain waves can be defined, can we then determine variations from this form in children, in older people, and in people with mental disease?"

At Cambridge, Dr. Walter A. Rosenblith, Associate Professor of Communications Biophysics at the institute, summed up: "The development of this specialized equipment is not only a tribute to Dr. Wiener's ideas; it is also a very practical illustration of the way in which medicine, the biological sciences, mathematics, and electrical engineering combine forces to attack age-old problems."

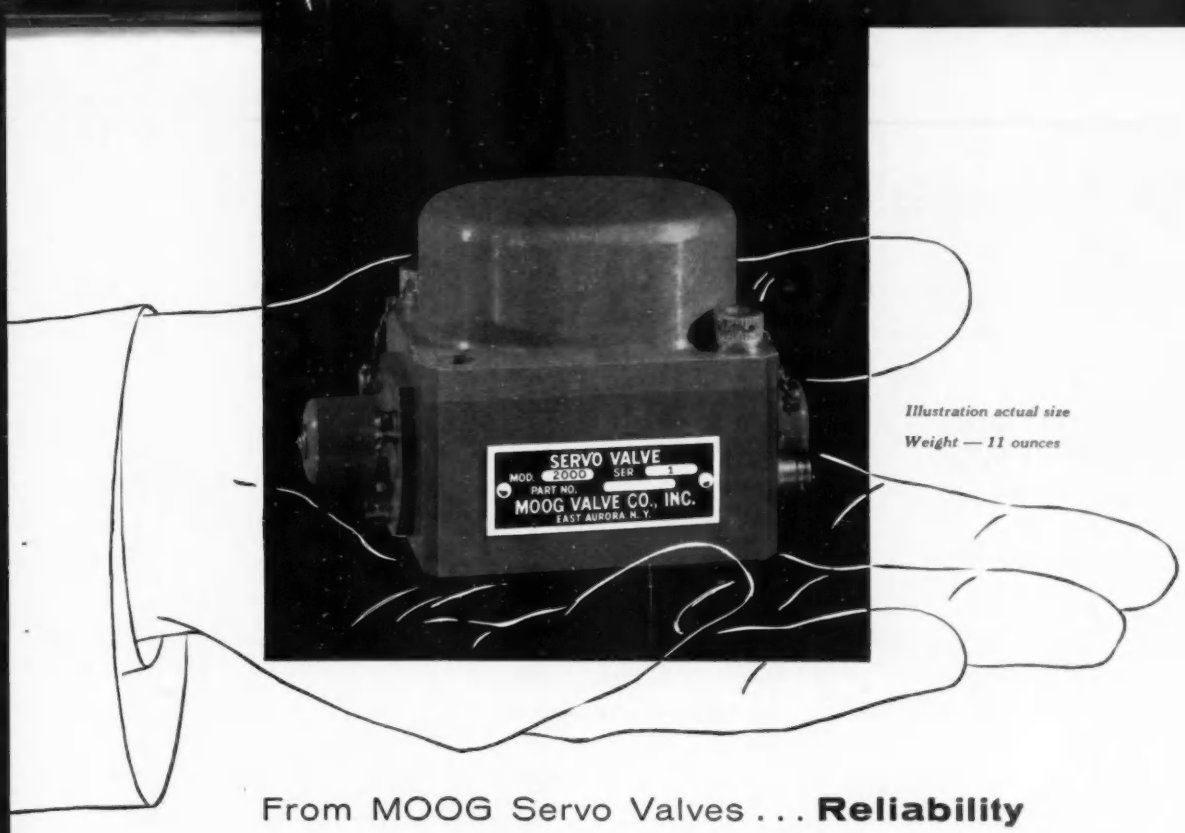


Illustration actual size

Weight — 11 ounces

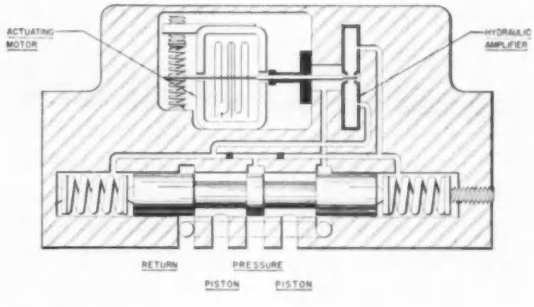
From MOOG Servo Valves . . . **Reliability and High Dynamic Performance**

Many thousands of Moog Servo Valves are now in use in exacting applications on advanced aircraft and guided missiles. This widespread usage attests to Moog features of reliability and high performance which have gained for these units recognition as the industry standard.

Now, these same features may be obtained in Moog's new Dry Solenoid Servo Valves. These units, illustrated above by Model 2000, feature a torque motor that is isolated from contact with the hydraulic fluid. The Dry Solenoids have been developed for those systems in which the fluid might otherwise contaminate the torque motor. They are even smaller and lighter than other Moog units of the same flow capacity and comply with requirements of MIL-H-5440A.

Moog Servo Valves are proportional type, electrically actuated, hydraulic, four-way valves featuring high dynamic response, sensitivity, linearity, small size and low weight. Production models are designed to operate in hydraulic systems of from 1000 to 3000 PSI pressure. Rated output flows from 0.1 to 50.0 GPM for control currents between 2.0 and 40.0 milliamperes as specified are available in production units.

Conventionally, valve input is from a balanced push-pull DC amplifier and valve flow output is applied to a piston or hydraulic motor. An electric signal proportional to piston position or motor angular rotation is fed back to the amplifier to give a closed servo loop.



For details write for Bulletin 2000-2

MOOG VALVE CO., INC. PRONER AIRPORT EAST AURORA, N. Y.

Mettler

PRECISION WEIGHING for QUALITY CONTROL

Linear dimensions, as well as many other properties, have a definite relationship to the weight or mass of an object. By weighing, this relationship can be examined quickly and efficiently for production and quality control purposes.

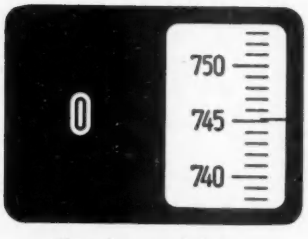
The simple, fast and accurate METTLER balance is the ideal tool for this important task.

The METTLER Type K-5 precision balance has a capacity of 2000 grams (4.41 lbs. av.). The pan, completely unobstructed, is on top of the instrument. The projected optical scale covers a range of 1000 grams (2.205 lbs. av.) with 1 gram (0.0353 oz. av.) per division. This scale can be read quickly and easily to 0.2 grams (0.00705 oz. av.).

The balance is built on the pendulum principle. The magnetic damping of the swing of the beam is so very effective that reading of the weight can be made less than 3 seconds after the object has been placed on the pan.

METTLER Type K-5 precision balance

BELOW 5/6 actual size reproduction of weight scale demonstrating easy readability

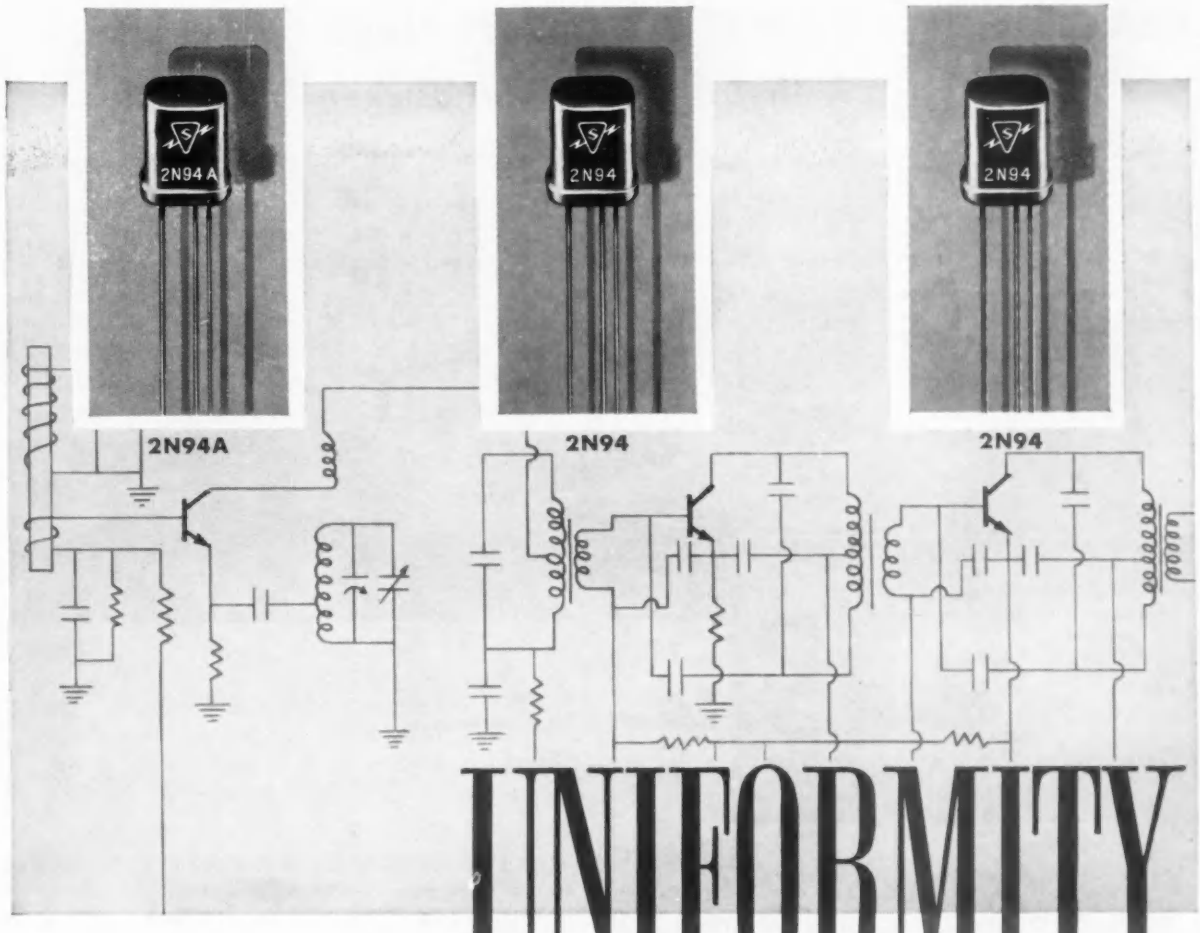


Showing weight reading 745.2 grams

- **SPEED** — One weighing takes not more than 3 seconds
- **CAPACITY** — 2000 grams (4.41 lbs. av.)
- **READABILITY** — Optical scale of 1000 grams reads easily to 0.2 grams (0.00707 oz. av.)

- **Additional models of greater or smaller capacity and different tolerances of accuracy are in process of development. Write for further information or service.**

METTLER INSTRUMENT CORP. HIGHTSTOWN N.J.



UNIFORMITY

...for more gain from stage to stage without preselecting

For your broadcast applications, Sylvania high frequency transistors Type 2N94 and 2N94A offer higher gain without preselection by stage. Production is simplified; performance is more stable; servicing problems are minimized.

Low collector capacitance and ease of neutralization account for this important advantage. In a typical broadcast application, the addition of a single 10 μμf capacitor in the collector circuit of IF and RF stages provides adequate neutralization.

Uniformity is obtained through unique construction techniques permitting close production control.

In computer applications Sylvania Transistors offer quick recovery time for high speed switching and provide higher gains at higher operating currents.

High Frequency Transistors
Type 2N94 (3 mc alpha cutoff)
Type 2N94A (6 mc alpha cutoff)
featuring
- high gain
- high uniformity
- low collector capacity
- ease of neutralization

Low Frequency—High Gain
Type 2N34 (PNP)
Type 2N35 (NPN)
—for low to medium power use. Gains up to 40 db in grounded emitter circuit

High Power—Low Frequency
Type 2N68 (PNP)
Type 2N95 (NPN)
—increased power ratings—to 2.5 watts. Use for high current, low voltage applications (6—24 volt power supplies)
Type 2N101 (PNP)
Type 2N102 (NPN)
Similar to types 2N68 and 2N95 without cooling fins. Power dissipation 1 watt.

For complete information on Sylvania Transistors write to Department G16R.

"Another reason why it pays to specify Sylvania"

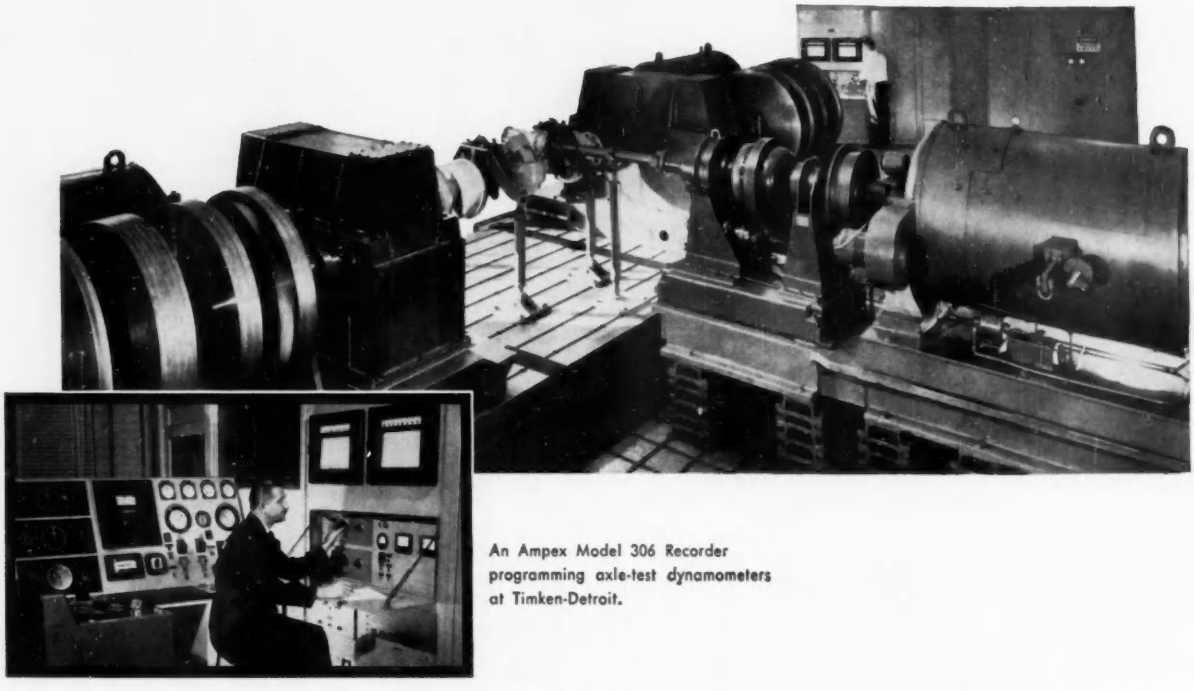
SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC., 1740 Broadway, New York 19, N. Y.
In Canada: Sylvania Electric (Canada) Ltd., University Tower Building, Montreal

LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

MAGNETIC TAPE RECORDING

helps ***Road-Test*** *Timken Truck Axles*



An Ampex Model 306 Recorder programming axle-test dynamometers at Timken-Detroit.

Magnetic tape recordings are now being used to duplicate rugged road-tests at the Timken-Detroit Axle Division of the Rockwell Spring and Axle Company, Detroit, Michigan. A four hour tape cycle is made of actual road surface and driving conditions . . . then played back through torque and speed dynamometers — repeatedly — until a test axle breaks down.
Result: more realistic and efficient testing — better axles for today's trucks, buses and trailers.

WHY TIMKEN CHOSE AMPEX

Timken engineers required a recording and playback medium that could give near-perfect reproduction of the original road test phenomena . . . and would playback indefinitely without introducing errors through wear and speed irregularities. They found that the Ampex F-M recorder best met these exacting requirements. Its extreme stability of tape motion, precise timing and consistent accuracy produced laboratory "road-test" results within 1% of actual conditions.

LET AMPEX STUDY YOUR REQUIREMENTS

Ampex manufactures the most complete line of magnetic recorders for complex and sensitive automation, communication and data-handling systems. Why not let Ampex application engineers determine what magnetic tape recording can do for you?

For further information, *send for our 16-page illustrated bulletin, "Data Recording, Machine Control and Process Regulation." Contact your nearest Ampex representative or write to Dept.* HH-1897

AMPEX CORPORATION

ANOTHER APPLICATION BY THE INSTRUMENTATION DIVISION OF

AMPEX CORPORATION • 934 CHARTER STREET, REDWOOD CITY, CALIFORNIA

Branch Offices: New York; Chicago; Atlanta; San Francisco; College Park, Maryland (Washington D.C. area).
Distributors: Radio Shack, Boston; Bing Crosby Enterprises, Los Angeles; Southwestern Engineering & Equipment, Dallas and Houston; Canadian General Electric Company, Canada.

FINANCIAL AID TO HIGHER EDUCATION

Business Help for Our Colleges A Job for All Business Firms

IN recent months, individual business firms have announced the adoption of a variety of plans, both imposing and ingenious, for financial aid to higher education in the United States. In doing so, they have taken a lead in dealing with a problem of transcendent importance both to the business community and to our nation as a whole.

Previous editorials in this special series have shown that:

1. Our colleges and universities, and particularly the independent, privately endowed institutions, are in grave financial difficulties.
2. These difficulties promise to become much more acute in the years immediately ahead unless extraordinary steps are taken to relieve them.
3. A financially crippled system of higher education is a major national menace.

If, however, the business community is to play an adequate part in helping our colleges and universities financially, the plans adopted by business firms thus far constitute merely a beginning and a set of guide posts. What is required is a general movement on the part of business firms to go to the financial aid of higher education. Such a movement would involve a myriad of individual company plans which, in the nature of the case, cannot be expected to bring great renown or publicity to their sponsors.

Rescue Operation Is Feasible

For the business community as a whole it is feasible to make a major and possibly a decisive contribution to putting our colleges and universities back on their feet financially. One percent of business profits before taxes would do it. In 1954 business profits before taxes were about $35 billion. If one percent of these profits, or $350 million, were contributed to our independent, privately endowed colleges and universities it would enable these institutions (1) to increase the salaries they pay by $200 million a year, and (2) to provide $150 million more for modernization and maintenance of their establishments. In the opinion of competent authorities, this would put these institutions in relatively good working order financially, a process to which a matching grant of $50 million by the Ford Foundation for the improvement of faculty salaries will make a large contribution. It would add about one-fourth to their present annual outlay of about $1.4 billion.

Such a contribution from business would not meet the needs of the independent institutions for new buildings and equipment required to accommodate the great increase in college enrollment anticipated in the years immediately ahead. Neither would it relieve the financial problems of our tax-supported colleges and universities. As a group these institutions have fared better financially in recent years than the

independent institutions. But they also face grave financial problems, particularly in the provision of adequate faculty salaries. It would be far simpler, however, to solve the financial problems of the tax-supported institutions if the independent colleges and universities were back on their feet financially.

One Dollar Does Work of Two

The federal government exempts 5 percent of business profits from the tax imposed upon them if the 5 percent is devoted to religious, charitable or educational purposes. (Most profits are taxed 52 percent.) A contribution of one percent of business profits to higher educational institutions would exhaust only one-fifth of this allowance. It would bring to about two percent the total share of business profits going to both educational and charitable purposes.

In 1953, business firms contributed about $400 million, or slightly more than one percent of profits before taxes to educational and charitable purposes of all kinds. Of this total about $75 million went to educational institutions, mostly colleges and universities.

For some companies it is feasible to contribute more than the average contributed by business generally. Indeed, some companies not only utilize their full 5 percent of tax-deductible funds for charitable and educational purposes but go beyond it. For other companies in financial difficulties no contribution at all is possible.

If, however, those business firms for which it is financially feasible contributed one percent of their profits before taxes to our colleges and universities, the problem of adequate support for the crucially important business of higher education would be far along the way to successful solution. **In 1954 a contribution of one percent of their profits before taxes, or about $350 million, would have reduced business profits after taxes by only about half that amount. This would have meant a reduction of about $175 million, out of a total of about $17.8 billion of profits after taxes.**

Attractive plans to channel financial aid from business to higher education have been abundantly demonstrated recently. These plans, for the most part the creation of large corporations, have included not only a broad array of scholarship grants, but such ingenious arrangements as that by which a company matches with its funds the gifts its employees make to the colleges of which they are alumni.

A full array of these plans, some of which were discussed in an earlier editorial in this series, has been prepared by The Council for Financial Aid to Education (6 East 45th Street, New York City 17) and is available for the asking. Also, colleges and universities have established in most states and regions cooperative associations to help business help them. The Commision on Colleges and Industry (912 Kahn Building, Indianapolis 4, Indiana) distributes a directory of these associations. And, of course, the colleges themselves are always eager to discuss their financial problems with business people and suggest constructive solutions.

Only Small Start Made

The plans for business aid to education which have recently attracted national attention constitute the conspicuous sort of leadership which it is the privilege and opportunity of our great corporations to provide. But the job is too large to be handled by a small number of business firms, no matter how bold or ingenious their programs.

To put our colleges and universities back on a firm footing financially the help of the great rank and file of business corporations is required. All of them, large and small, have a crucial stake in seeing that this job is done. The future of America will be decisively shaped by what happens in and to our college classrooms.

This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments that are of particular concern to the business and professional community served by our industrial and technical publications.

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Donald C. McGraw

PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.

It's in the Bag!

Fresh, Clean Ink for a Year of Trouble-free Recording

★ You won't have any messy, time-consuming re-inking of pens on the new Bailey Recorders. The entire system is white-glove clean—hermetically sealed, non-evaporating, non-corrosive. Gone is any chance of sludge or oxide formation. Gone are clogged pens, interrupted records, unsightly splashes.

The transparent plastic ink sacs are changed once a year—that's all. Capillary tubing carries fresh, clean ink to the pens continuously without any day-to-day attention.

This exclusive new inking system* is only one of the many time-saving, money-saving distinctive features of the new Bailey Recorder.

Ask for Product Specification E12-5. P34-1

*Now available for the New Bailey Recorder only.

ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER

- Pre-calibrated plug-in receiver units
- Up to four pneumatic or electronic receivers —or two receivers and two integrators
- Any four variables on one chart—easily read and interpreted
- A full year's ink supply at one loading
- Faster ordering—from stock
- Minimum inventory of parts
- Minimum instrument investment for process cycle expansion or alteration

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Controls for Power and Process

BAILEY METERS
Controls for
TEMPERATURE
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FLOW · LEVEL
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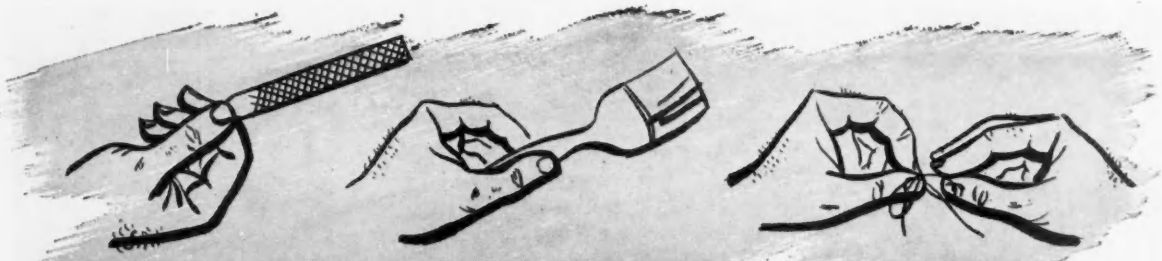


HANCOCK

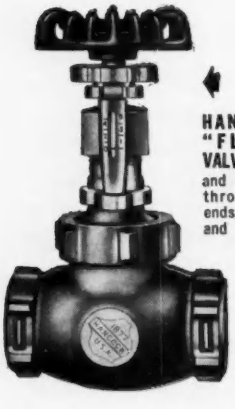
"FLOCONTROL" VALVES GIVE YOU PIN/POINT CONTROL

Here's manual control of flow, temperature and pressure that's really precise. Hancock "Flocontrol" Valves, with micrometer dial and pointer mounted on the bonnet, permit settings to within 1/100th turn of the handwheel! Equally important, any setting can be duplicated easily, perfectly — any time.

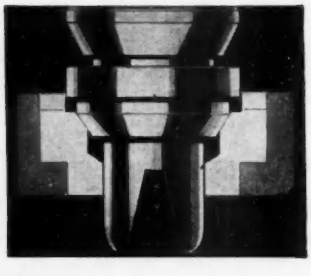
Hancock "Flocontrol" "3 in 1" design gives you the advantages of a variable orifice, plus a shut-off, plus an index... all in "one package." Bronze and steel types are available. Both have a scientifically designed V-Port valve disc that *compels proportional flow throughout the entire lift of the valve stem.* The shut-off seating surface is entirely removed and separate from the controlling V-Ports. Super-finished "500 Brinell" stainless steel seats and discs minimize the effects of wire-drawing and steam cutting.

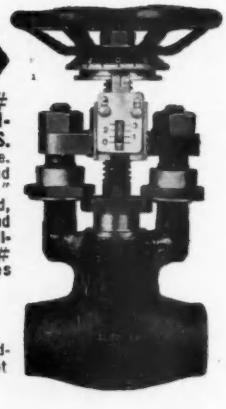
For fine throttling control and proportional flow... for greatest efficiency, lowest operating costs — install strong, dependable Hancock "Flocontrol" Valves in your lines. Your nearby Hancock Distributor will gladly give you full details.

When Hancocks go in, valve costs go down



HANCOCK BRONZE "FLOCONTROL" VALVES. Types: Globe and Angle. Sizes: ¼" through 2". Screwed ends. Available in 150# and 300# Series.





HANCOCK 600# STEEL "FLOCONTROL" WELDVALVES. Types: Globe and Angle. Outside Screw and Yoke. Sizes: ¼" through 4". Screwed, Socket Welding and Flanged Ends. Available with 150#, 300# and 600# Series Flanges.

VALVE SEAT AND V-PORT DISC fully closed. As the valve is opened proportional flow is gradually increased. The Hancock "Flocontrol" Valve has straight-line flow. Its regulation does not depend on the short-wearing, fine threads common to a needle valve.

YOUR LOCAL INDUSTRIAL SUPPLY DISTRIBUTOR is as close as your nearest telephone. His 24-hour emergency service and large stocks of the finest supply items simplify your purchasing and save money for you.

HANCOCK VALVES

A product of **MANNING, MAXWELL & MOORE, INC.** Watertown 72, Massachusetts

MAKERS OF 'HANCOCK' VALVES, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS, AIRCRAFT PRODUCTS. BUILDERS OF "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

Case No. 64

Kemp Dryer
Assures Accuracy
For Sun Oil Co.

How SUNOCO® guarantees dependable instrument readings 24 hours a day

WHEN the Sunoco Plant at Marcus Hook, Pa., introduced a new process at the beginning of the year, many new instruments were installed. To dry the compressed air operating these instruments and assure accurate readings, Sunoco installed a Kemp Model 300 S Dryer.

Kemp Dryer Entirely Satisfactory

According to Harold Powers, Instrument Supervisor at Sunoco, the Kemp Dryer has been entirely satisfactory in performance. Operating continuously day and night since installation, it has performed according to specifications, has never been saturated, and has required very little attention.

Kemp Dryers for Every Purpose

Kemp offers a variety of dryer models to meet all problems. Designed to dry air to sub-zero dew points at low cost, they are constructed of quality materials and embody the engineering knowledge gained from Kemp's many years of experience. They are available with manual, semi-automatic, or fully automatic tower reactivation. In addition, Kemp will prescribe the proper desiccant for each specific drying job. If you have a problem involving the removal of water from air, gases, or liquids, contact Kemp engineers now.

Accurate readings depend on constant, dependable supply of dry air. Harold Powers, Instrument Supervisor at Sun Oil Company's Marcus Hook plant, is shown reading two of many instruments relying on Kemp-dried air to assure dependable readings.

For more complete facts and technical information, write for Bulletin D-27 to:
THE C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.

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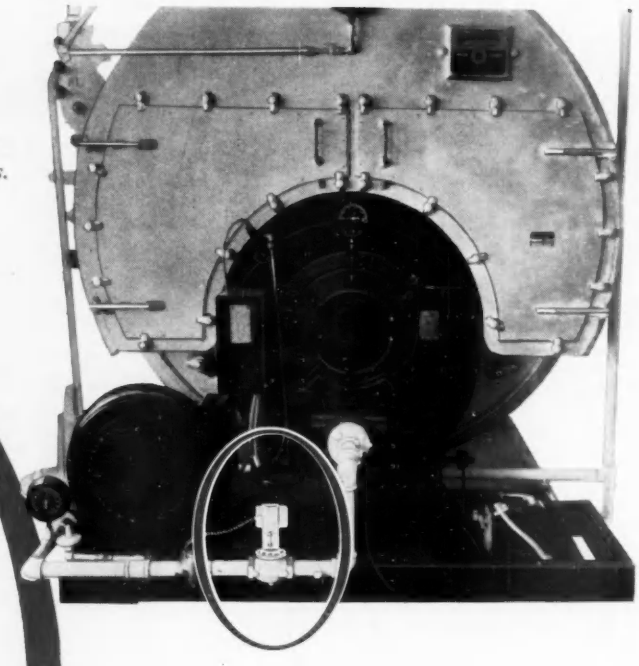
DYNAMIC DRYERS

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • INERT GAS GENERATORS
SINGEING EQUIPMENT

Factory Mutual and Underwriters Laboratory Approved. Fast-Closing... Fast or Slow Opening to fit any combustion requirements. Optional Accessories for Special Needs.



General Controls' new H-series Hydramotor gas fuel valves

FAST-CLOSING GAS VALVE
opens the way to Better Boiler Control

General Controls
NEW
H-Series
HYDRAMOTOR
Gas Fuel Valves

This new successor to General Controls' famous G-2 Hydramotor valve does even a better job...closing in one second or less in no-lag response to sensitive limit control commands (or power failure). Positive spring action guarantees this—with General Controls' single seat design to assure *really* tight shutoff, and electro-hydraulic action for ample opening power. All parts inside the cast iron body are aluminum or stainless steel, good for any gas. Overported body provides maximum capacity at minimum cost. Make it a policy to insure premium performance on every boiler job with General Controls' new H-series Hydramotors. Write for catalog with full details today.

GENERAL CONTROLS

MANUFACTURERS OF AUTOMATIC CONTROLS FOR HOME, INDUSTRY AND THE MILITARY

GENERAL CONTROLS • PERFEX CONTROLS

40 FACTORY BRANCH OFFICES SERVING THE UNITED STATES AND CANADA

FIVE PLANTS: IRON MOUNTAIN, MICHIGAN • GLENDALE, CALIFORNIA • BURBANK, CALIFORNIA SKOKIE, ILLINOIS • GUELPH, CANADA

Italy Looks At America's Control Market

When busy, clever Italy bounded into today's free-wheeling export market, America responded to handsome Italian craftmanship in divers objects such as "espresso" pots, car styling, and sewing machines. Will Italian designs soon invade our control field?

Last September's First International Instrument Exposition touched off this possibility. When Italian manufacturers heard of this Philadelphia show they tried to organize a collective exhibit—similar to displays by France, Britain, Sweden, and Japan. But the project fell through for want of Government support. And instead, a team of Italian experts were sent to Philadelphia to see how they **might** have fared.

Che cosa e instrumentation?

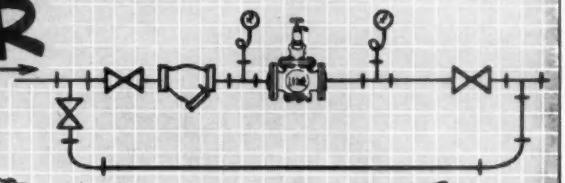
The Italians sailed home tantalized and disappointed. Like most international exhibitors, they had misjudged the show's intent. The fine optical and laboratory-type goods that are prime Italian stock-in-trade were apparently a very minor part of what America called "instrumentation." Unprepared, they had run smack-dab into the overwhelming scope and diversity of a huge trade display of industrial control equipment.

Back in Italy, retrospect revealed a David and Goliath situation. The "instrumentation" part of Italy's great "Associazione Industriali dell'Ottica" (Association of Optical Goods Manufacture) accounts for barely 10 per cent of its activities. Producers of meters and control equipment for industry employ only 2,400 workers with a total yearly output valued at around $6 to $7 million. This figure is slightly less than American control exports each year to Italy. Italian manufacturers are apparently hard enough pressed to get their product into domestic factories in the face of American competition—much less sling it overseas at the American Goliath.

Outsold by those they'd like to sell

But the returning experts' thoughtful report offers more than despair to chew on. For one thing, it has high praise for the American habit of specialized trade shows. "It is worth while noting," they wrote, "that such exhibits are more important for exhibitors than the general fairs, even if visited by millions." The Italians were impressed with the serious audience, the "incredibly lavish" free literature, the skilled booth attendants.

WHEN TO USE A REGULATOR



SELF-CONTAINED PRESSURE, TEMPERATURE AND PUMP PRESSURE REGULATORS

Leslie Self-Contained Regulators are spring loaded, internal pilot, piston or diaphragm operated with stellited seating surfaces, hardened stainless steel main valves and renewable wearing parts of heat treated stainless steel of grades best suited to the application.

Regulators are used for any one or any combination of the following conditions:

★ When quick response is necessary to handle sudden load changes.

★ When available fluid pressure supplies sufficient differential for self operation.

★ When positive dead end shutoff is required for short periods of time.

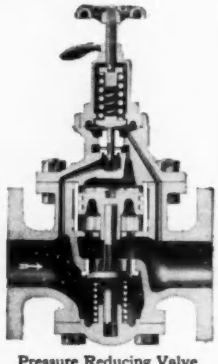
★ When one-step pressure reductions are desired.

★ When service conditions require continuous flow for varying demand.

★ When "instrument control" is required without auxiliary operating force.

★ When installation requires smallest physical dimensions.

★ When operation from either a nearby or a remote control station is desired.

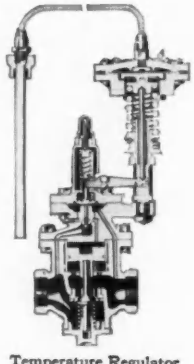


Pressure Reducing Valve
Class L-3

LESLIE
PRESSURE REDUCING VALVES

Automatically maintain a constant reduced pressure of steam, air or gas. Single seated, tight closing. Respond instantly to load changes. Renewable, interchangeable parts. Stellited seating surfaces. Complete overhaul permitted without removing body from pipe line. Made in bronze, cast iron, cast steel or cast alloy steels. Sizes ½″ to 6″. Other units available for constant differential pressure, unloading, and for remote adjustment. Inlet pressures 25 psi to 1500 psi steam at 950°F. Reduced pressures 2-600 psi.

SEND FOR BULLETIN 5302



Temperature Regulator
Class LTCO

LESLIE
TEMPERATURE REGULATORS

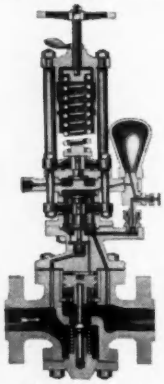
Designed for a wide range of applications. Vary the flow of steam or cooling water to heater or process to automatically maintain constant temperature. Rugged 100° F. adjustable range thermostatic element. For small and large flows, direct operated, direct and reverse acting or with "Duomatic", two-element (pressure and temperature) control. For driers, fuel oil heaters, instantaneous and storage heaters, kettles, open tanks, ovens, process heaters, degreasing machines, steam tables, sterilizers, storage heaters, urns, etc.

SEND FOR BULLETIN 5307

LESLIE
PUMP PRESSURE REGULATORS

Accurately and automatically control discharge pressure from steam operated, reciprocating or turbine driven pumps. Single seated—positive—responsive and accessible. No packed plungers or stuffing boxes. Built for constant discharge pressures of 8 psi to 2000 psi and excess pressure of 10-200 psi. For motor-driven pump discharge pressure recirculation.

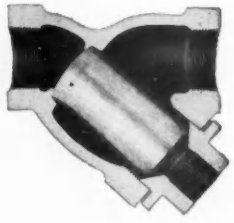
SEND FOR BULLETIN 5306



Pump Governor
Class CTHS-3

LESLIE
SELF-CLEANING STRAINERS

Recommended to protect all regulating equipment from dirt and foreign matter. Cast iron, bronze, cast steel, carbon moly, chromemoly, stainless and forged steels. Strainers with screwed, flanged, socket and butt welded connections; sizes ⅛″ to 10″ inclusive. Primary service ratings to 2500 psi. Screens furnished in Monel and stainless steel with various perforations and meshes for liquid, gas, air, oil and steam services. For complete details on each type, ask for Bulletin 5308.



Self-Cleaning Strainer

LESLIE REGULATORS

SINCE 1900

LESLIE CO., 211 GRANT AVENUE • LYNDHURST, N. J.

"STILL FAR AHEAD IN QUALITY AND PERFORMANCE"

And awed by the product clinics boldly conducted in groups by competing manufacturers.

The Italian team has this to say about American control product: Even the measuring instruments turned out by "mass production" seem to have remarkably fine finish. Yet construction principles are quite similar to Italian. But even more startling are the sophisticated electric, electronic, and pneumatic control modes the U. S. A. has developed. And the fact that American prices manage to run about 20 per cent less.

However, after touring all show aisles they conclude that the U. S. lags behind Germany and Italy in the matter of standardization—"the unification of instrument dimensions and electrical characteristics."

A long pull to the American market

Suppose Italy overcomes these shortcomings in cost, quantity, and complexity. How will it break into the American market?

Some formidable obstacles are noted by the visiting group. The need for American agents and service—above all, service—is stressed. "How could a North American purchase an Italian instrument if he is not sure that there will be someone to set it up, afford technical assistance, and attend to small repairs?"

And will Italian makes become known in America? Experience with an Italian camera here indicated publicity and propaganda costs of around 100 million lire (about $150,000). No doubt American control competition would force equally fierce expenditure.

One of the experts closes the report on this doleful note: "My daily experience with almost all foreign markets leads me to the conclusion that the American market is certainly the most difficult and the most disappointing."

But don't sell the Fine Italian Hand short on this one note of un-Latin pessimism. It has overcome obstacles before in reaching America.

a message

to Original Equipment Manufacturers Who Use Permanent Magnets

May we have 1 minute and 2 seconds to tell you why Indiana Steel Products Company can do the best job, and the most thorough job, of supplying your permanent magnet requirements?

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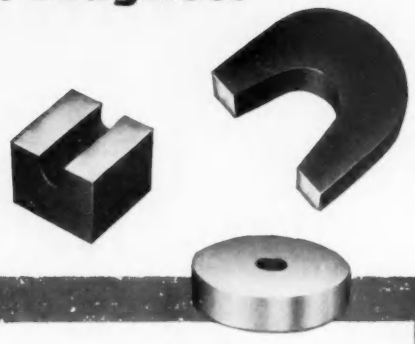

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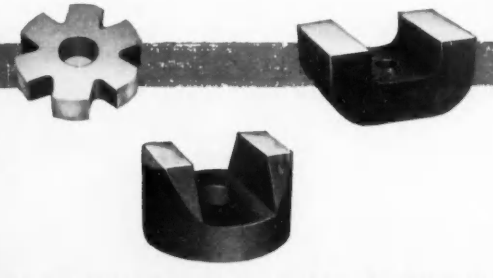

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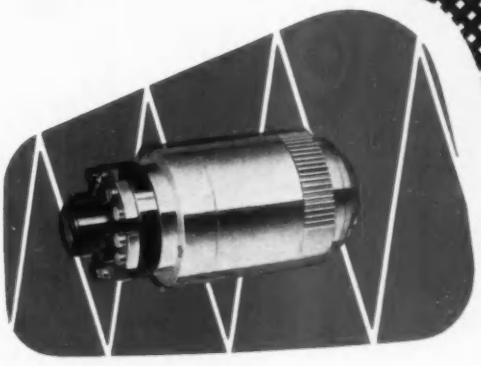

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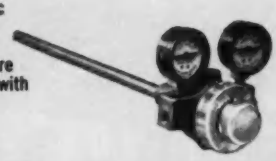

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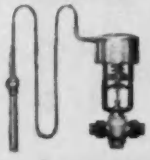

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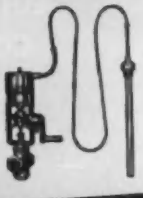

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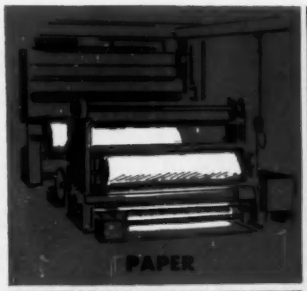

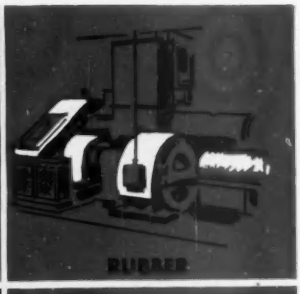

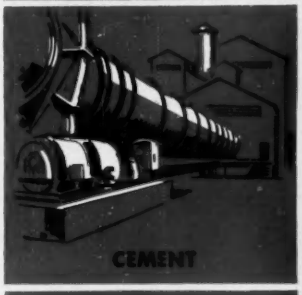

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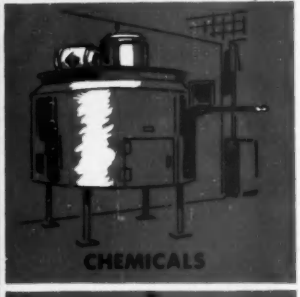

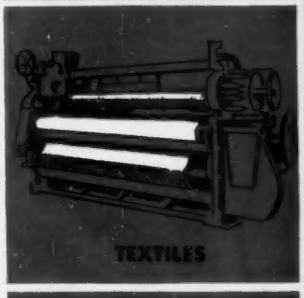

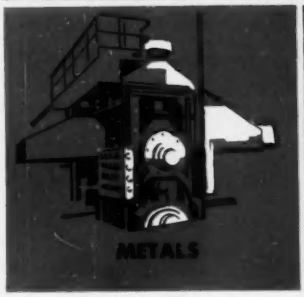

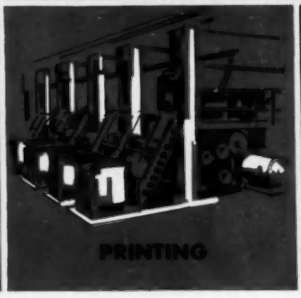

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JULY, 1955

Data Processing Takes Teamwork

Too often, when planning an electronic data processing system for application in a business office, management poses the categorical question, "Shall we use our own business personnel or shall we hire expert computer engineers?" The most fruitful approach — a teaming-up of business and engineering personnel — is not considered.

The present lack of teamwork is apparent. Early in March the American Management Association held a conference on electronic computers in New York. And on exactly the same dates the Western Computer Conference was held in Los Angeles. Here is a spectacle: 1,300 business men gather on one side of the continent to discuss computer applications, and 1,300 engineers convene on the other side to discuss computer equipment. In their independence and disregard of the others' practical knowledge lie the dangers, for business men tend to overestimate the capabilities of the electronic equipment and engineers tend to oversimplify the business problems. The danger is brought home forcefully by case histories on record in which both business men and engineers, working independently, have arrived at exceedingly low estimates of the number of programming steps or the time required for processing business problems. They have been low by as much as a factor of fifty.

Business men are prone to pattern their programming for a data processor after existing business routines. The engineer can inject logic and knowledge of the data processor's capabilities. The results of teamwork will be new business methods and optimum use of the equipment: first, to determine the most efficient use of data processors for routine clerical operations, and secondly, to study the use of information for management decision-making.

It takes time to build an effective composite team. The business man and the engineer become impatient with each other. The business man should not try to master the computer completely. Nor should the engineer try to become a business expert. But each should learn about the other's problems so that he can cooperate effectively. The mutual rewards: optimum problem analysis and optimum equipment use.

E. M. Grabbe

Facts that Influence Your Approach to

TELEMETERING

WALTER E. RUFLETH, The Bristol Company

Here is information that answers important questions about time-impulse telemetering. Without going into nuts-and-bolts, it will help you choose component types with an eye to system performance and economy.

3 BASICS TO CONSIDER . . .

. . . in selecting a telemetering system are the variables you wish to measure, how often to measure them, and the terrain to cover. Here are some of the facts that may influence your decisions:

1. THE VARIABLES Most industrial variables can now be measured and converted into a form that can be transmitted electrically. Their number and variety influence circuit complexity and appearance of the receiving panel. Some variables now being successfully telemetered:

pressure	liquid level	current and voltage	motion
flow	pH	BTU's	horsepower
temperature	electrical power	speed	wind velocity

2. THE FREQUENCY While the majority of telemeter systems in service today are the continuous, point-to-point recording type, complex networks and interrelated variables are making sophisticated approaches more and more necessary. The problem usually boils down to these questions: how often is measurement necessary, and what is the least costly way to install and run the system?

Five types of hook-ups are:

Continuous — where variables are critical and need constant watch

Intermittent — where variables need only be checked at intervals

Continuous-Intermittent — where it is possible to separate more critical variables for constant and intermittent telemetering

Grouped-Multiplex — where several measurements can be transmitted as a group over a single circuit into a "multiplexed" receiver

Successive-Multiplex — where measuring points over a long area can be "multiplexed" at intermediate locations, then herded to the panel.

3. THE TERRAIN The type of interconnecting circuit between the measuring transmitters and central panel usually depends on the terrain: its topography, weather, and degree of settlement. Hence, signals may be carried by one, or combinations of three basic media:

Air — various types of radio can be used to take signals over mountains, deserts, and seas.

Wire — strung wire and regular overland circuits can cover plant and rural areas.

Underground — in urban areas signals can be carried by underground leased lines

Telemetering today is an industrial tool of great utility. It is a flexible and surprisingly economical means of remotely supervising, directing, and controlling a variety of processes, activities, and procedures. Yet while the concept is well accepted, and its uses well explored, the actual selection of a system of transmitters, multiplexers, interconnections, and receivers, poses a troublesome problem to some engineers. First—

Do You Know Your Variables?

The first consideration is the number and type of variables on which information is desired. In selecting a telemetering system it is necessary to know how many *different* variables must be supervised, as well as the *total* number of measurements needed. The appearance of the receiving panel and the number of separate receivers largely depends on these factors. Obviously, individual instrument scales and ranges will be required to gather accurate data on each variable (see Table I). Once similar measurements are placed on the same receiver, however, there is a promise of great economy.

Another factor is the importance of the variable from a time standpoint. Consider a municipal water system where it is only necessary to occasionally check the water level in a number of uniform size reservoirs. It is conceivable that a dispatcher could operate fairly well with just one indicating telemeter receiver by selectively dialing each transmitter. While this extreme austerity in panel boards is seldom attempted, modifications of it are in service.

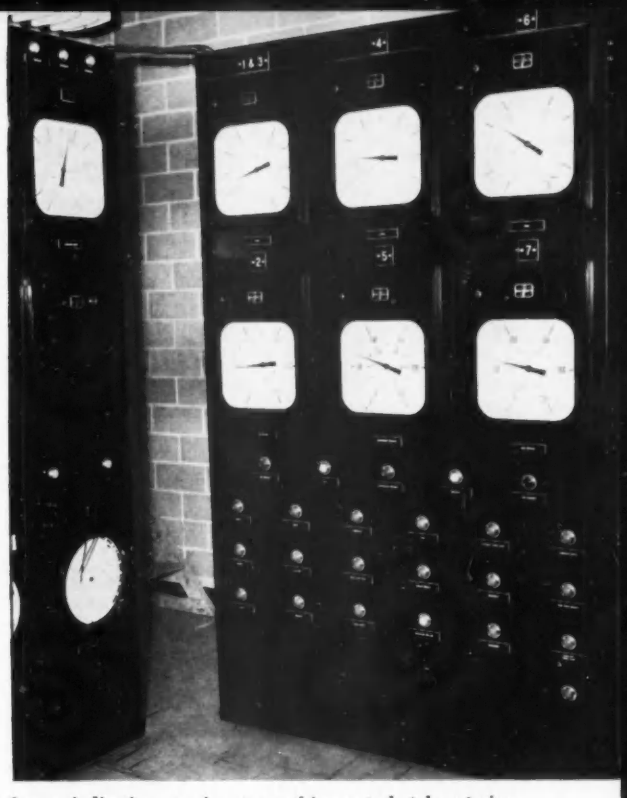
The dispatching panel shown in Figure 1 uses a selective call telephone dialing network to get information from 49 field locations with only seven receivers. A system of bullseye lights, lighted nameplates, and illuminated instrument faces tell the dispatcher which instrument to read. The instruments all measure pressure or differential pressure—hence the small number of receivers. And in this instance no permanent record of conditions is required.

How Often Will You Measure?

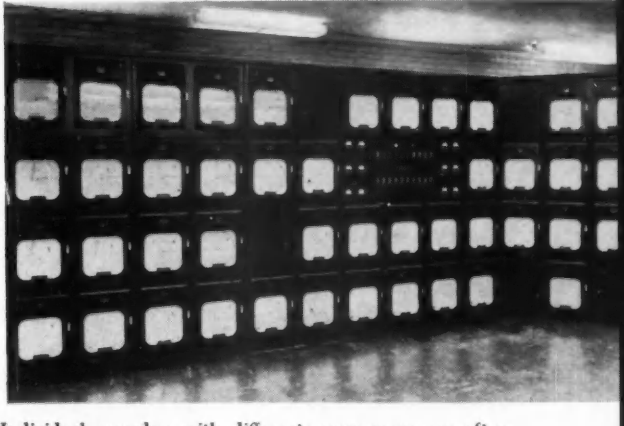
The next question involves frequency of measuring. In the case above it is enough for the dispatcher to know his pressures at relatively infrequent intervals, usually every hour. If more frequent information or continuous records of every change are needed, the panel must obviously bear more receivers.

There is little doubt that the "workhorse" of telemetering—in terms of wide industrial use—is the continuously recording type, where a record of every variable is essential. A large scale example of this is in Figure 2, where 44 recorders keep track of pressure and flow of coke oven and blast furnace gas at 55 points in a Chicago area steel mill.

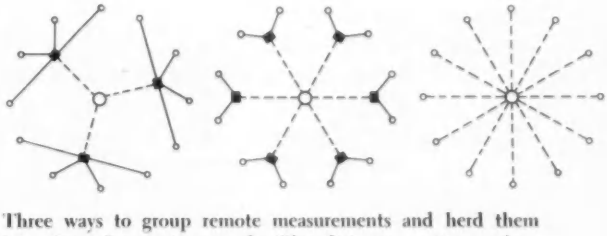
Compromises in this matter of signal frequency are sometimes advantageous. For instance, the



Seven indicating receivers on this central telemetering panel measure gas and differential pressures at 49 locations. A telephone network dials them in. FIG. 1



Individual recorders with different range spans are often necessary for continuous records of many variables. This panel brings in 55 measurements in a steel mill. FIG. 2



Three ways to group remote measurements and herd them into the telemetering panel. The first two patterns show signals subgrouped for retransmission. FIG. 3

THREE VARIATIONS IN

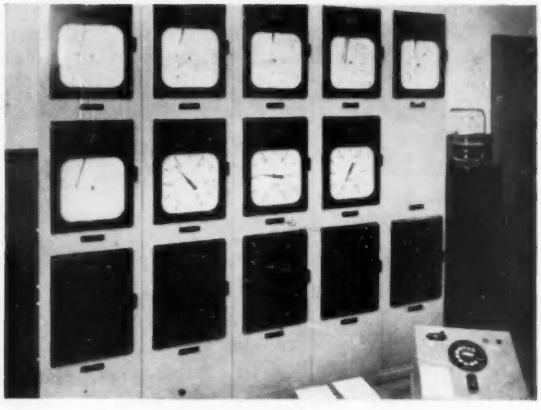
1. CONTINUOUS-INTERMITTENT

It is often necessary to compromise between continuous and intermittent coverage of telemetered points in a complete system. This installation shows how such a compromise was made without any loss in critical coverage or operating value.

THE PLACE: Lower New England network of the Algonquin Gas Transmission Co., Boston

THE JOB: Keeping track of gas temperatures and pressures in the network to permit load shifting by remote control.

Telemetering instrument panel in Algonquin's Boston dispatch office. The recorders continuously log critical variables. The indicators bring in other points through the multiplexers (below) and the telephone-type dialing unit in the right foreground.



Algonquin Gas's Boston panel. FIG. 4

2. GROUPED-MULTIPLEX

Study of the geographic distribution of measuring points in a telemetering system often suggests a way to group signals to save equipment and circuitry. This installation employs only one telephone circuit to carry information from six outlying measuring stations.

THE PLACE: New England Div. network of the Tennessee Gas Transmission Co., Agawam, Mass.

THE JOB: To read pressures at principle delivery points and control them at the New York and Mass. state line.

Tennessee Gas's central telemetering panel at Agawam, Mass. Two multiplexing instruments at the bottom of the panel feed readings from east and west to recorders. A third circuit from the south goes to individual static pressure recorder.

Tennessee Gas's Agawam panel. FIG. 5

3. SUCCESSIVE-MULTIPLEX

When measuring points are located at intervals over a long system it often is practical to set-up intermediate stations and "cascade" readings into the central panel. This busy installation covers a wide geographic area economically and efficiently with only four telemetering circuits.

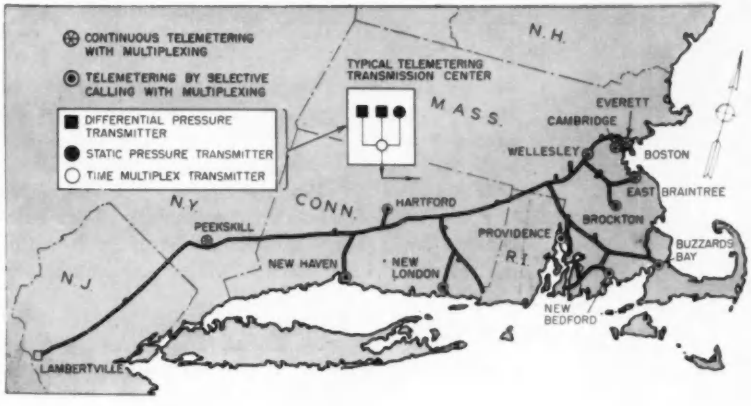
THE PLACE: Piedmont Natural Gas Co's section of the Transco gas pipeline that crosses the mid-south.

THE JOB: Recording and accounting for gas consumption from 48 measuring points in and around eight major southern cities.

Twenty-two two-pen recorders and four single pen units are served by four multiplex receivers on this central panel at the dispatching office in Charlotte, N. C.

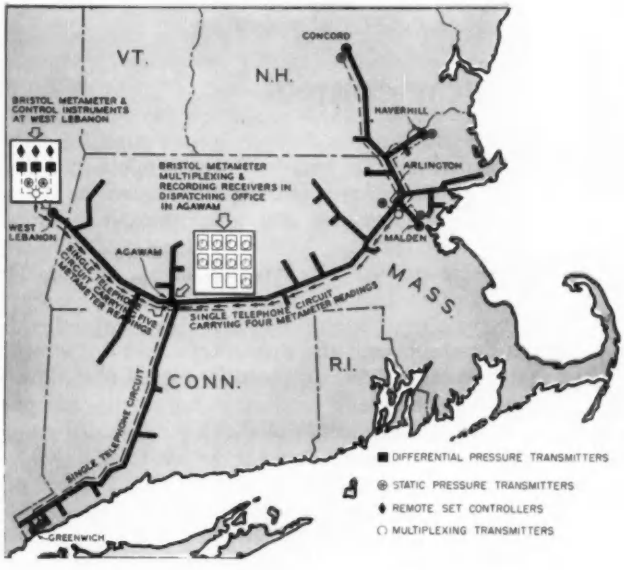
Piedmont Natural Gas's Charlotte panel. FIG. 6

TELEMETERING NETWORKS



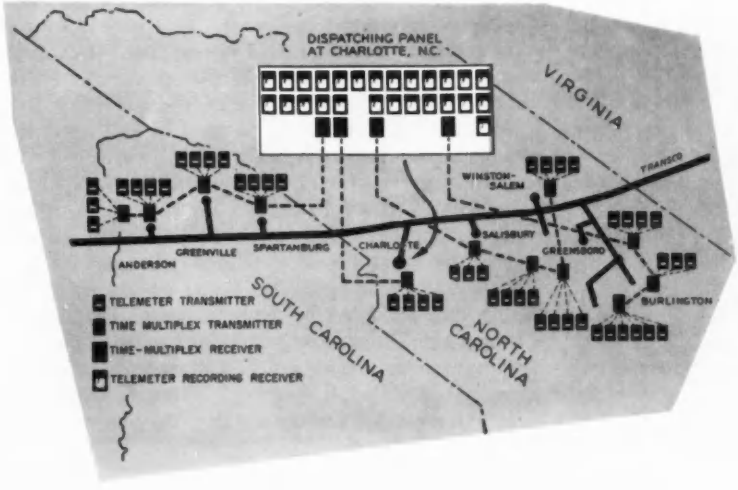
DETAILS:

As the map shows, this dual system brings gas temperature and pressure readings from 13 transmission centers over 500 pipeline miles into Boston. Continuous recording of down-stream and differential pressures is required in the populous Boston and Peekskill areas. Hence the need for a multiplexing system, which segregates and directs impulses into the proper recorder. Each of the seven outlying metering-regulating stations is dialed hourly to obtain less critical indicated readings. Signals come over wires leased from local telephone and telegraph companies.



DETAILS:

Four readings of static pressures at the eastern end of this gas pipeline network are multiplexed and sent sequentially over a single leased telephone circuit to central dispatching headquarters 83 miles away. From the western end, five readings of static and differential pressure are multiplexed and transmitted to Agawam over another single circuit. A single static pressure reading is brought up from the south. The system controls delivery of gas into the pipeline at West Lebanon, N. Y., by a coded feedback dialing on the same telephone circuit.



DETAILS:

Gas users are strung all along this one pipeline, which spans the south. Hence it is expedient to group three or more transmitters, multiplex, and feed the signals into an intermediate multiplex receiver-transmitter. The latter, in turn, retransmits into still another intermediate multiplex receiver-transmitter further down the line. And the "cascading" is repeated until the full capacity of the multiplexing equipment is reached. In this way as many as 15 measuring points are brought together and channel on one circuit into headquarters. And, only four individual circuits serve 48 widely scattered points.

Supply into Tennessee Gas Co.'s New England pipeline network is remotely controlled through these pneumatic valves. FIG. 7

Algonquin Gas Transmission Co. of Boston combines continuous recording and selectively indicated measurements on its dispatching instrument panel. Full details on this continuous-intermittent system are provided in Table 2. The main consideration in this approach is the number of variables that must be supervised *at the same time, and the frequency with which they must be checked.*

In transmitting signals to a central panel board, the geographic distribution of the measuring points must also be considered. Take twelve measuring stations equally spaced around the periphery of a circle. The most obvious interconnecting system between transmitters and central receivers would be twelve separate wire circuits. But studies may reveal that grouping, or multiplexing, several of the readings and transmitting them as a group over a single circuit to a multiplex receiver at the center would be more efficient and economical. The second installation covered in Table 2 is a good example of this.

What is Multiplexing?

A word about multiplexing. Most electrical telemetering now is based on impulse-duration or time-impulse signals. The length (or duration) of the impulse is proportional to the measured variable. In multiplexing, it is possible to herd several of these impulse trains into one transmitting instrument—the multiplex transmitter. The multiplexer then sends measurements of each variable in a definite timed sequence along a single circuit to the dispatching office. Finally, a multiplexer receiver in the office segregates the various signals and directs them to appropriate recorders or indicators.

Still another example of multiplex dexterity is shown in the third installation in Table 2. Obviously, engineering a "compromise" system will depend upon distance and load factors, as well as orientation of measuring points to the central panel.

What Connectors Will You Use?

Once the location of measuring transmitters is decided on, the type of interconnecting circuits is determined. As Table 1 indicates, geographic factors heavily influence a decision here. Also, further balancing is required in comparing cost of leased lines against private wires and radio type transmission.

Actually, each method of interconnection can be effective in different circumstances. The least expensive way consistent with dependability under conditions at hand should be the aim here. Each installation seems to have its own unique requirements.

What About Auxiliary Functions?

Telemetering systems offer interesting opportunities for auxiliary functions. There are a number of jobs that can be handled effectively over the same circuit that transmits the information signals. It is simply a matter of building proper auxiliary equipment into the initial installation.

REMOTE CONTROL

Telemetering really puts on long pants when the loop is closed and remote control is established from the central station. Naturally, this cannot be accomplished in every case. But where possible, it usually proves a bonanza.

There are two main types of remote control. The first and most simple is remote-manual, where operation of a valve, motor, pump, or fan is controlled by pushbutton from the dispatcher's desk. The other is "remote-set set point" automatic control. This is just what the name implies: an automatic controller at the remote location produces a signal that guides the dispatcher in resetting at the set-point.

A good example of remote-set is the Tennessee Gas New England installation described in Table 2. Flow of gas into this pipeline network takes place at West Lebanon, N. Y. This flow can be altered automatically by the central dispatcher at Agawam, Mass. He simply dials a code number on telephone selector equipment and resets the control point on the pressure controllers that operate the valves shown in Figure 7. There are six code numbers, two for each valve. One code raises the set-point by a given amount, the other lowers it. Limiting devices prevent any disastrous effect from misdialing.

Another example of automatically controlled telemetering is shown in Figures 8A and 8B. A municipal water distribution system in an eastern seaboard city uses a group of scattered reservoirs at high elevations to supply water to its customers. These reservoirs are filled by booster pumps that operate from main lines connected to two low elevation primary water storage areas. The pumps are automatically controlled through telemetered signals from the reservoirs or standpipes that they supply. The

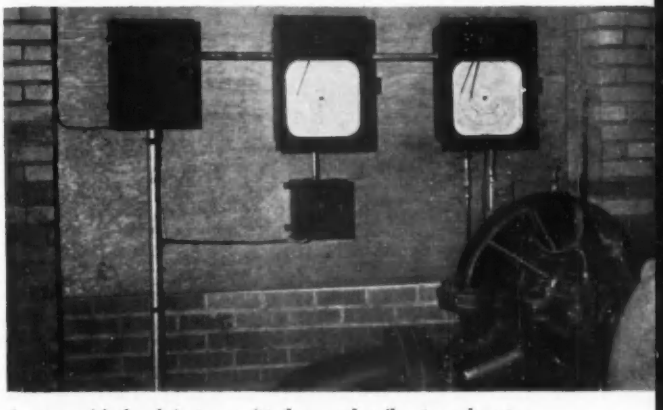
telemeter receiver-controller shuts off the pump when water reaches its proper level in the tank, starts it again when the level falls to a certain point. Thus reservoir levels are always maintained, despite their location several miles from the booster pumps.

Can You Use Auxiliary Receivers?

Sometimes it is advantageous to have more than one receiver per variable in a telemetering system. In the Algonquin gas transmission system shown in Table 2, information on pressure and differential gas pressure is transmitted back to the company's dispatcher so that he can be sure there is enough gas in the line to satisfy all his customers. Also, at several of the metering points that are on a "selective call" basis, the transmitter signals a recording receiver in the customer's dispatch office to keep him abreast of conditions that could affect his plant.

How About Communications?

Where remote control is not present it is often possible to do the job by "verbal feedback" to personnel at the station. Either auxiliary voice transmission or teletypewriter equipment works here. Instructions from headquarters based on telemetered information, and on-the-scene observations help relatively inexperienced local personnel keep things in trim. Two way communication often saves a lot of leg work for "experts" from headquarters.



A reservoir's level is transmitted several miles to a booster pump station to automatically balance a water shed. FIG. 8

TELEMETERING PROBLEMS AND SOLUTIONS

CONDITIONS	POSSIBLE SOLUTIONS
CASE A: Large number of measurements of same type of variable from different locations, i.e., oil levels at a tank farm, water levels in a municipal water system, static pressures or flows in a gas transmission system, temperatures of bearings.	Measurements from transmitters dialed selectively (manual telephone selector equipment), or scanned automatically (sequential multiple scanning switch) on just a few indicating receivers; or continuously recorded on separate receivers.
CASE B: Groups of related variables, not identical as to type of magnitude, but each equally important, i.e., static and differential pressure and temperature in gas transmission; temperature, differential temperature, and Btu's in air conditioning; level, flow, and sluice gate position in waste disposal.	A small group of indicating receivers, one receiver for each primary measurement but selectively or automatically connected into groups of transmitters at different locations; or a battery of unit groups of recording receivers, each group covering conditions at a given location.
CASE C: Large number of similar variables, located in groups or singly, at points distant from each other; certain groups or measurements very important economically or operationally, others not so important.	Multiplexing of groups where geographically advantageous, continuous recording of the most important measurements, selective or automatic scanning of less important locations.

TWO SHORTCUTS FOR

Selecting a Precision Trimmer

How important is an adjustable trimming resistor's resolution and drift? In many industrial applications these factors are negligible. But in precision control they can be critical. Here a graph and formula pinpoint their importance.

FRANK BRADLEY, Consultant, The Ahrendt Instrument Co.

Many servo and computer applications require highly accurate control of the voltage gradient across a computing element or transducer. Conventionally, an adjustable trimming resistance in series with the primary element, Figure 1, controls this voltage by adjusting the voltage drop across the trimmer.

Essentially, there are two important factors to consider in selecting a precision trimmer: 1) the trimmer should be settable to the correct value; and 2) once adjusted, the ratio of trimmer resistance to primary element resistance should remain fixed. The characteristics that express these factors are:

- Initial accuracy (corresponds to trimmer resolution)
- Differential resistance drift between trimmer and primary element

Although the objective of this article is to present a graph (next page) as a shortcut device, the following equations lead to the approximations used.

Initial Accuracy (Resolution Effects)

Referring to Figure 1, this relationship is evident:

$$\frac{e_o}{e} = \frac{R}{R + \frac{nkR}{N}} = \frac{1}{1 + \frac{nk}{N}} =$$

$$1 - \frac{nk}{N} + \left(\frac{nk}{N}\right)^2 - \left(\frac{nk}{N}\right)^3 + \cdots$$

Trimming involves setting e_o/e to some desired value. However, since n varies in integral steps, e_o/e varies in steps. To estimate the magnitude note that the largest step occurs between $n = 0$ and $n = 1$. By subtraction

$$\text{Resolution step} = \frac{e_o}{e}(n = 0) - \frac{e_o}{e}(n = 1) =$$

$$\frac{k}{N} - \frac{k^2}{N^2} + \frac{k^3}{N^3} - \cdots$$

FIG. 1

Trimmer adjusted so that e_o/e is specified ratio — $\frac{n}{N}$ = **Fraction of trimmer in circuit**

R = Potentiometer resistance

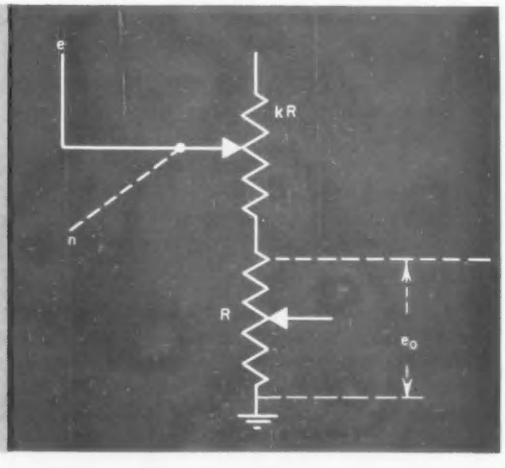
kR = Total trimmer resistance

N = Trimmer resolution, turns of resistance wire

n = Trimmer shaft rotation, an integer between 0 and N

c = Differential temperature coefficient of resistance between potentiometer and trimmer, expressed in parts per million per deg C

Δt = Positive or negative ambient temperature range



USE OF GRAPH

HORIZONTAL LINES — Resolution in turns of resistance wire

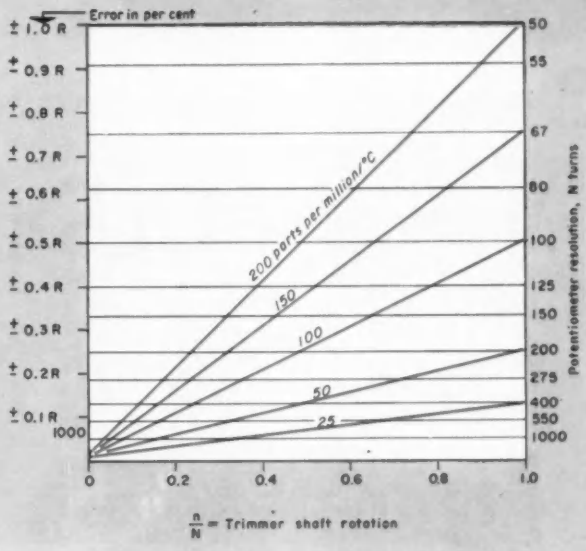
SLOPED LINES — Differential temperature coefficient in parts per million per deg C (plotted for plus or minus 50 deg C change)

TOTAL ERROR — Sum of resolution and differential temperature errors at given shaft rotation

EXAMPLE: Consider trimmer having resolution of 400 turns of wire and differential temperature coefficient of 50 ppm per deg C. Drift error exceeds resolution error at 50 per cent trimmer shaft rotation and

$$\text{Error (in per cent)} = 0.125 + 0.25\,\frac{n}{N}\,k$$

This may be assumed a reasonable error distribution. On the average, temperature and resolution produce equal error. Over a plus or minus 100 deg C range the equivalent requirement would be potentiometer resolution 400 turns, differential temperature coefficient 25 ppm per deg C



This may be approximated conservatively as $k/_N$. Since it is possible to approach a desired value of e_o/e within, at worst, one half the resolution step, the maximum resolution error is $k/_{2N}$.

Drift Effects

The major cause of drift is differential temperature coefficient of resistance between trimmer and potentiometer, which, over wide ambient temperature ranges, may result in substantial ratio changes. Drift due to aging is a secondary consideration in adjustable circuits where such drift may be adjusted out at periodic intervals. Drift due to differential self-heating is also normally small in precision applications because of adequate power ratings.

Referring to Figure 1

$$\frac{e_o}{e}\,(\Delta t) = \frac{R}{R + \frac{nkR}{N}\,(1 + c\,\Delta t)} = \frac{1}{1 + \frac{nk}{N}\,(1 + c\,\Delta t)}$$

Drift due to differential temperature coefficient is

$$\frac{e_o}{e}\,(\Delta t) - \frac{e_o}{e} = \frac{1}{1 + \frac{nk}{N}\,(1 + c\,\Delta t)} - \frac{1}{1 + \frac{nk}{N}}$$

$$= -\frac{nk}{N}\,c\,\Delta t + \left(\frac{nk}{N}\right)^2 (2c\,\Delta t + c^2\,\Delta t^2)$$

$$- \left(\frac{nk}{N}\right)^3 (3c\,\Delta t + 3c^2\,\Delta t^2 + c^3\,\Delta t^3) + \cdots$$

Making the same conservative approximation,

$$\text{Drift} = \frac{nk}{N}\,c\,\Delta t$$

Using the Graph

$$\text{Resolution produces an error } E_R = \frac{k}{2N}$$

$$\text{Drift produces an error } E_D = \frac{nk}{N}\,c\,\Delta t$$

The former is independent of trimmer setting; the latter is directly proportional to trimmer setting. Plotting these errors against an abscissa of trimmer shaft rotation results in the graph above. Resolution errors are horizontal lines, the error amplitude being inversely proportional to 2N; these lines are marked with the resolution (turns of resistance wire).

Drift errors are straight lines, of slope $c\,\Delta\,t$ (the factor k is included in the ordinate scale in both cases). To construct these sloping lines it has been necessary to assume a temperature difference $\Delta\,t$; plus or minus 50 deg C was used. The lines are individually marked as to the differential temperature coefficient. The ordinates referring to the sloped lines are linearly related to temperature difference, i.e., double ordinates for plus or minus 100 deg C temperature change.

A Formula for Pinpointing Resolution

If the assumption is made that the resolution error is to be equal to the average temperature coefficient error, the following relation between resolution and temperature coefficient may be deduced.

$$N = \frac{10^6}{C\,\Delta t}$$

where: N = trimmer resolution, in turns of resistance wire
C = differential temperature coefficient between trimmer and trimmed element, in parts per million per deg C
Δt = max. temperature deviation above average, in deg C

On this basis a trimmer with a temperature coefficient of 250 parts per million per deg C in series with a potentiometer having a temperature coefficient of 20 ppm per deg C, and which is to be operated over a range of minus 55 deg C to plus 105 deg C would require a resolution of

$$N = \frac{10^6}{270(80)} = 47 \text{ turns of resistance wire}$$

What PULSES Can Do For You

A. A. BLUNDI, Electronic Instruments Div., Burroughs Corp.

THE GIST: Electronic pulses are the vital heartbeat in a wide variety of control, timing and sequencing devices. Pulses throb in high-speed computers, feedback control systems, telemetering and electronic test apparatus. Thus, a basic understanding of pulse—its capabilities and limitations— is important to those who stake their future in control.

This article examines the means by which pulses store useful information and initiate or control desired operations. Some functions of the many pulse control devices covered: generation; storage; delay; gating; mixing; grouping; sampling; counting; distributing and sequencing. Here is a short but searching course in a fundamental yet versatile tool of control technology.

An electronic pulse is a rapid surge or variation in voltage (or current). It is a discrete unit: a single signal with a beginning and an end. Characteristically, it is of relatively short duration on the time base being considered.

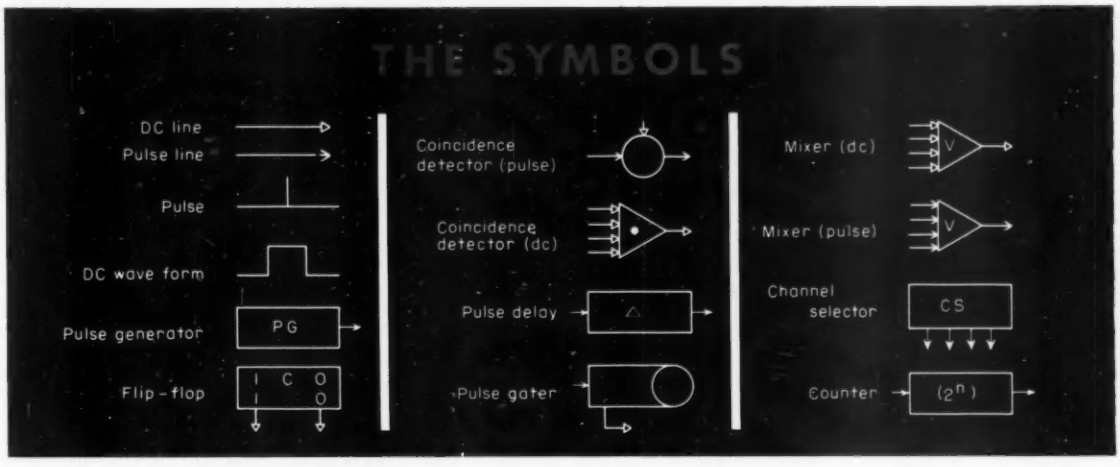
A pulse can assume several shapes, including a half sine wave or a crude square. But because of its relatively short duration it is commonly designated by a vertical line of no time dimension—a pip. Its shape is usually determined by the way it is generated and by the input requirements of the equipment that it must trigger or control. For example, a typical line of pulse controlled devices is designed to operate on 0.1 microsecond, half sine wave pulses. This facilitates matching members of the series into integrated systems.

Useful electronic pulses have many sources. In electronic computation, control and test systems, these fit into three categories:

- Pulse generators: These usually contain no useful information. They time, sequence and otherwise control pulse systems. Available pulse generators will deliver uniform pulses at precision rates ranging from pushbutton speeds well up into the megacycle range.
- Magnetic tape, punched cards or punched paper tape: Pulses fed into a system by these sources contain information—data and instructions in coded form—needed to perform a desired computation or control action.
- Repeated physical phenomena: pulses may be direct representations of these phenomena. For example, transducers can convert a bottle count or shaft rotation into pulses that can be used in control systems.

Why Pulse Techniques?

In most systems, pulses and pulse handling equip-



ment process data, compute, and control. Pulses have several inherent advantages that help them perform these functions. One is range. Pulses can be triggered at pushbutton rates or at high megacycle frequencies. Because of the high frequencies, pulse controlled systems can operate at high speeds. Another advantage is precision. Since pulses are discrete units, they are either present or not present. Counting and control thus nears the precision of numerical computation.

Pulses also can serve as a direct analog of the binary system of numbers. In the decimal system of counting, each digit of a number is represented by a power of ten, while in the binary system each digit is a power of the number two. A system of notation to express the binary system thus requires only two symbols of states, each representing one of the two possibilities of the binary digit—a *0* or *1*, Table I.

Since the *0* state can be represented by *no pulse* and the *1* state by a *pulse*, pulses can be coded into an electronic representation of binary arithmetic. Used in this way, pulses form the basis for electronic digital computation. And for a wide variety of test and control systems that store and process information in binary form.

Pulses and pulse control equipment have yet another advantage: they lend themselves to logical analysis. Pulse systems can be laid out logically as block diagrams representing the functions to be performed: counting; delaying; shifting; stretching; and others. The equipment then can be assembled into useful systems on the basis of function alone. A detailed knowledge of what goes on within each unit is not necessary.

Next, let us look more closely at individual pulse functions. Nine of these are detailed in terms of logical building blocks that are assembled to perform various sequences of operations.

Table I

HOW TO FORM BINARY NUMBERS

	(2^3)	(2^2)	(2^1)	(2^0)
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0

THE FLIP-FLOP

The flip-flop circuit is a basic element in pulse systems and a key to many useful manipulations. It is commonly called a bi-stable storage unit since it remains in either one of two steady state conditions indefinitely until switched over by a pulse.

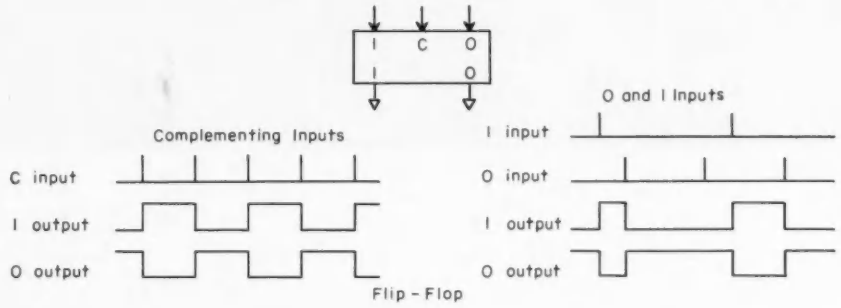
In its most common form, the flip-flop consists of two vacuum tube circuits coupled together so that either one or the other tube is conducting, but not both. The conducting tube will continue to function until a pulse triggers the second tube and causes it to conduct. The first tube then cuts off.

The accompanying diagram logically represents a flip-flop circuit plus its typical pulse functions. The flip-flop has two dc voltage outputs, one from each tube. Moreover, these outputs are 180 deg out of phase. When output *1* is high, the output at *0* is low and vice versa. The flip-flop has three switching inputs. A pulse fed into complement input C auto-

matically reverses the two tubes, regardless of the existing condition. Repeated pulse inputs at C therefore switch the state of the flip-flop back and forth between *1* and *0* and produce square-wave forms, 180 deg out of phase, at each output.

Inputs *1* and *0* have functions different from the C input. A pulse at the *1* input automatically sets the flip-flop to the *1* state, that is, makes the *1* tube conduct. If the flip-flop is already in that state it stays there. If it is not, it switches. Similarly, a pulse at the *0* input automatically sets the flip-flop in the *0* state.

The flip-flop has many functions in a pulse system. It can be used as a square wave generator having short rise and cutoff time. Its two stable states permit it to serve as a storage device for binary digits. Because pulse inputs control dc outputs, the flip-flop also can be used as a driver to switch vacuum-tube devices on and off, to control the flow of pulses, and even to count pulses.



GATING

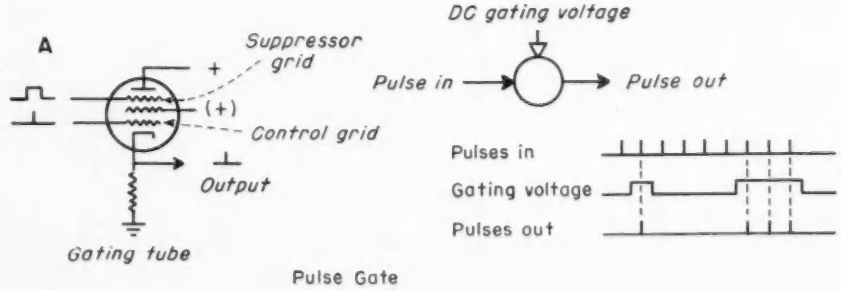
In pulse counting and control systems, the flip-flop normally teams up with a coincidence detector or gate. This unit literally gates the flow of pulses through it, passing or not passing pulses on to the output.

The most common coincidence detector is basically a special pentode (five-element) vacuum tube (A). Pulses to be gated are fed to the control grid of the tube, while one of the dc outputs from a flip-flop is fed to the suppressor grid. At steady-state conditions the tube does not conduct, and neither the pulse input nor the positive peak of the input from the flip-flop is enough to make it conduct. It takes the coincidence of both inputs—pulse and positive dc level—to make the tube conduct. When this happens, the pulse passes to the output of the coincidence detector.

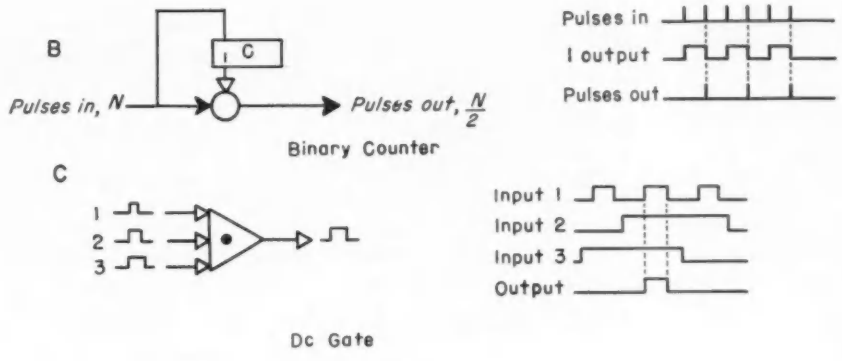
When a flip-flop and gate combine, they form the simplest type of binary counter. As shown in (B), the system is capable of counting by two. Assume that the flip-flop is in the *0* state so that voltage output at *0* is high. This means that the *1* output to the coincidence detector is low. The gate therefore is closed. The first pulse that comes along cannot get through the gate, but it does switch the flip-flop to the *1* state. Now the *1* output is high, thus permitting the coincidence detector tube to conduct when the next pulse comes along. Then the second pulse finds the gate open and passes through to the output, at the same time resetting the flip-flop to the *0* state. The cycle repeats for every two pulses. Only one pulse gets through for every two inputs. Counting will be covered more completely below.

In general, the coincidence detector performs the logical function of an *and* circuit. It delivers an output pulse only when both input pulse *and* dc gating voltage are present.

There are gates for dc voltages as well as for pulses. These devices, (C), deliver a positive dc gating output only when positive dc voltages are present at all of the inputs. By means of this dc gate, the combined outputs of several flip-flops can control a single stream of pulses.



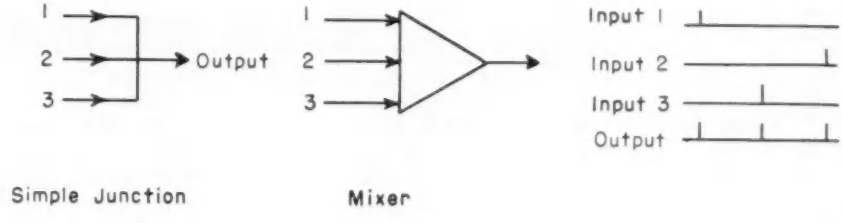
Pulse Gate



MIXING

Just as there is a logical *and* circuit in pulse work, so there is a logical or circuit. It's called a mixer. The mixer delivers an output pulse whenever a pulse is present at any one of its inputs; either on one input or another.

The simplest mixer is a junction point. In the junction shown, all pulses on the various input lines combine in the output. But mixing is not always as simple as this. Interaction between various pulse inputs may be objectionable. Then a special mixing device is used to isolate the various inputs from one another while passing on their combined information in a single output.



DELAY

Various devices are available that will delay pulsed information a preset amount of time. One type of delay employs a multivibrator circuit. An incoming pulse triggers the multivibrator which then generates a square wave of controllable duration. The trailing end of the multivibrator wave-form generates a pulse that appears at the output a set time after the arrival of the input pulse. Another type of delay uses lumped inductive and capacitive constants to slow down the pulse. Delays can be either fixed or variable In the latter case the variation can be continuous or in steps, depending on the degree of control required.

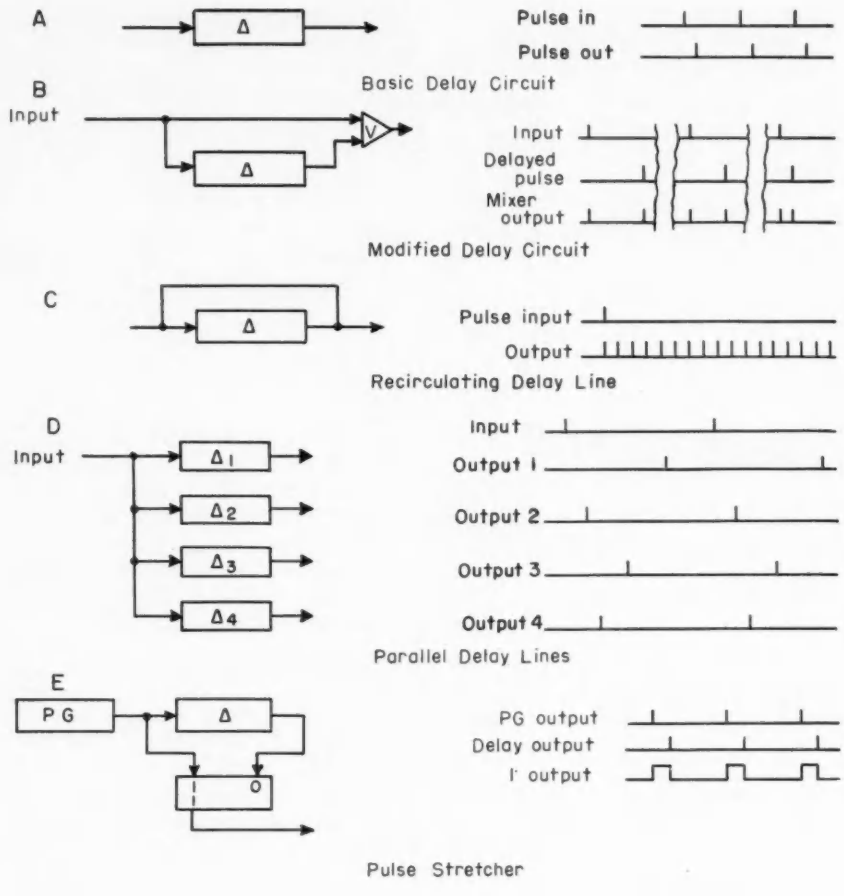
A simple modification of the basic delay circuit, (A), gives a system, (B), that can function as a frequency doubler or serve to produce two pulses at varying time intervals. In the latter case, the delay can test the resolving power of a pulse counter. That is, its ability to distinguish between two successive pulses.

The mixer is used in this system to prevent the delayed pulse from feeding back into the input to the delay. Leaving out mixer (C) reveals another function of the delay line in pulse systems: generation of bursts of pulses from a single input pulse. In the recirculating delay line each delayed output pulse feeds back to produce a continuous pulse stream.

By means of a suitable gating device, the pulse stream can be turned off after any given number of pulses. Controlled bursts of pulses generated in this manner are used to test crystal diodes and pulse transformers and to clear counters rapidly in computation work.

Delay networks using several delay lines in parallel may initiate several operations with a single input pulse. Thus, pulses from the timing track of a magnetic storage drum can be fed to four delay lines to set four functions in operation. (D) shows this arrangement.

As shown in (E), a delay line can be teamed with a flip-flop to trigger square pulses of desired width, or, in a sense, stretch narrow pulses into wider ones.

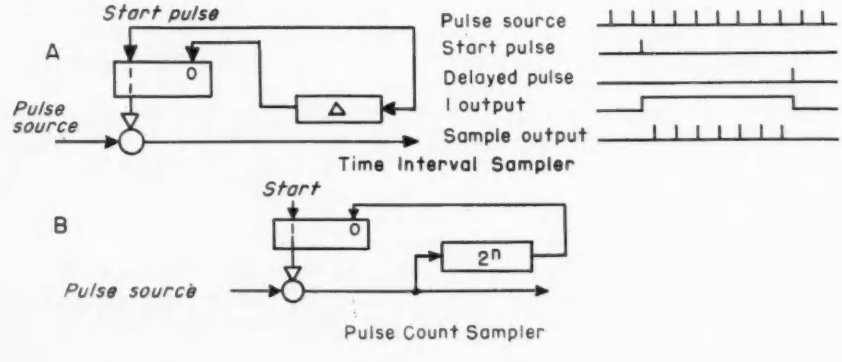


SAMPLING

Often bursts of pulses are obtained by gating a group of pulses from an existing source rather than by triggering. This is called sampling and can be done in several ways. One method, (A), is to use a delay to control a basic flip-flop and gate combination.

The *start* pulse opens the gate and sends a series of pulses to the output. The *start* pulse also triggers the delay, which shuts the gate after a certain time lapse. Thus the sample contains the number of pulses occurring within the delay line interval. This method of sampling is accurate to within one pulse.

If it is necessary to sample a definite number of pulses, a counter can be used instead of a delay unit, (B). The gate will then close after the desired number of input pulses, regardless of pulse frequency.

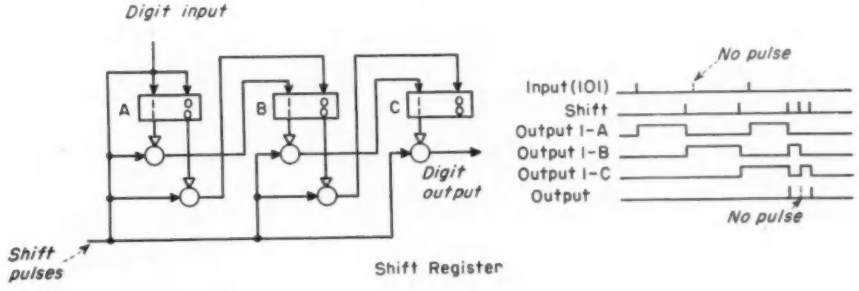


STORAGE

There must be means for storing pulses, since information for control operations often is used over and over again. There are many storage methods.

A flip-flop, capable of storing a single binary digit, is a common storage device. A delay line, another method, can store temporarily. Other common means are magnetic drums, electrostatic (cathode ray tube) devices, magnetic cores and magnetic tapes. Pulsed information can also be stored on punched cards or punched paper tape.

One type of flip-flop storage is the shift register. This device will accept a series of numbers and then shift out the numbers in sequence when properly pulsed. The shift register illustrated consists of a series of flip-flops connected so that binary digits can be fed from one to another until a complete binary number (a series of digits) is stored in the system.



COUNTING

There are many types of counting devices. Binary counters, decade counters, and ring counters are only a few. We've already seen how a combination of flip-flop and coincidence detector serves as a basic binary counter. It delivers one output pulse for every two inputs. Combinations of the basic system connected in series can be set up to count by any power of two. For example, a count-by-eight system, (A), contains three flip-flops.

At the start all flip-flops are in the *0* state. Therefore, all the *1* gates are closed. The first input pulse sets flip-flop *A* to the *1* position but cannot get through to flip-flop *B*. The state of the system after this first pulse is shown in the accompanying table. It represents a count of one. The second input pulse can now get through gate *A* to set flip-flop *B* to the *1* position. At the same time it resets flip-flop *A* to *0*. The table shows that the counter now reads *010* in the binary system, or two in the decimal notation. The process continues until the eighth input pulse produces an output pulse from the counter or until three flip-flops have passed through all the binary numbers from zero to seven. The table is identical to that used earlier to explain the binary notation.

This count-by-eight circuit can be converted to a system that will count by any number from two to eight. The output pulse is used to reset the counter. If five is the desired count, the output pulse is fed back to reset the flip-flops to the state *011* corresponding to a count of three. Thus the arrangement in (B) continually counts from three to eight so that it takes only five input pulses to trigger an output pulse.

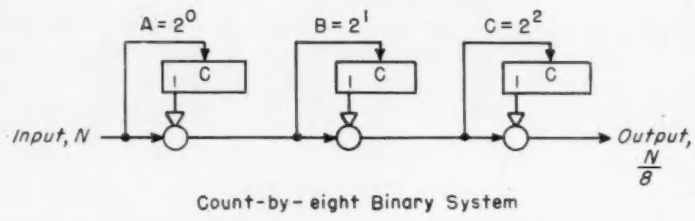
A ring type counter can also be built from flip-flops. This counter is so named because with each successive input pulse the count is passed from one flip-flop to another in a closed ring. (C) shows a typical unit. The table displaying flip-flop states for each successive input shows that the ring counter, unlike the binary counter, does not store the binary representation of the number of input pulses. For example, the binary representation of three is *011*. Instead, the count is passed from flip-flop to flip-flop. Since the output can be taken from any one of the flip-flops, the ring counter is also a pulse distributor.

Also note that three flip-flops used as a ring counter will only count by three. The same number of flip-flops used in a binary counter will count up to eight.

Other counters are built around components which inherently are counting devices. One such component is the beam switching tube, a high speed switching device that sweeps an electron beam through ten discrete positions. This tube functions as a decade ring counter and pulse distributor, (D). The count can be taken from any one target plate. At the same time dc gating voltages are available at each of the ten tube plates for gating and sequencing operations.

Useful variations of these basic counter circuits can be developed. One such adaptation is the bi-directional binary counter in (E). This system both adds and subtracts pulses. That is, it counts plus as well as minus inputs. The final flip-flop indicates whether the total is positive or negative.

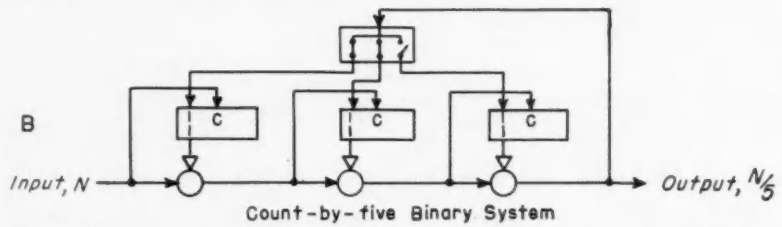
A



Count-by-eight Binary System

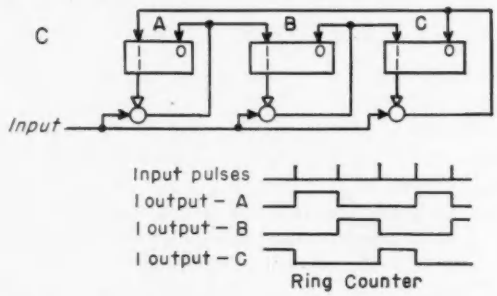
	C	B	A
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1
0	0	0	0

B



Count-by-five Binary System

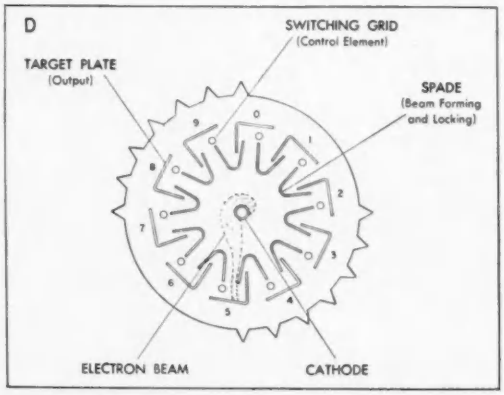
C

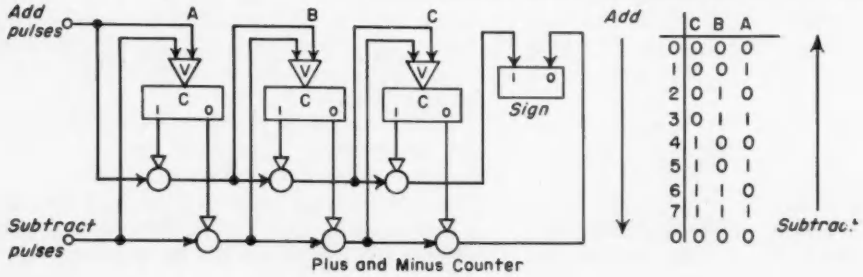


Ring Counter

	C	B	A
0	1	0	0
1	0	0	1
2	0	1	0
0	1	0	0
1	0	0	1
2	0	1	0
0	1	0	0

D





Plus and Minus Counter

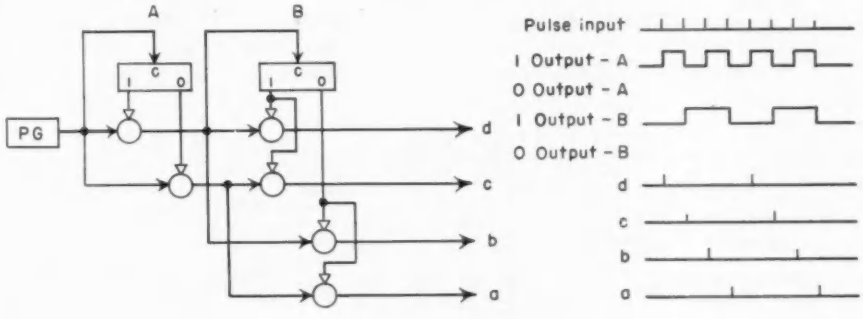
	C	B	A
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1
0	0	0	0

Subtract

DISTRIBUTING

In most pulse control and computation systems, pulses must be distributed to various output lines to perform desired control functions. It has been shown that the delay line, the ring counter, and the beam switching tube inherently function as pulse distributors.

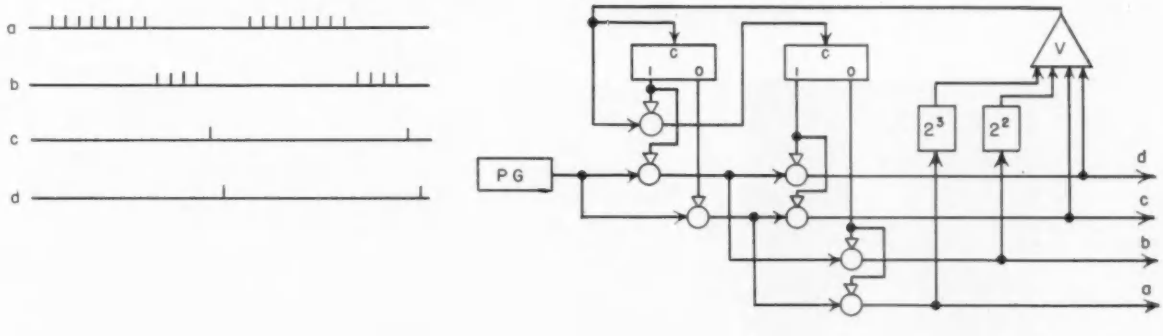
A simple binary flip-flop can also adapt to this function. The arrangement shown is actually a count-by-four binary system connected to four extra coincidence detectors. Input pulses are counted out in succession on four output lines.



SEQUENCING

The basic flip-flop counter can be modified to permit sequencing of pulses. In the arrangement shown, some of the connections have been changed and two counters, a gate and a mixer added. The *a* output is fed back through a count-by-eight unit. This permits eight pulses to be counted out on the *a* line before the flip-flops are advanced to switch the output pulses to the *b* line. The second counter in the system then counts out four pulses at *b* before an output can appear at *c*. The resulting pulse patterns are shown for each output line.

The pulse outputs from these sequencing and distributing networks can be used directly or converted to dc waveforms to drive vacuum tube circuits, gate other pulses, or control other units.



USING THESE FUNCTIONS

Now for a practical example of how basic pulse control functions can be connected together to form a working system. We shall consider a way to test the delay time of a multivibrator delay unit.

The purpose of the test is to compare periods of delay in repetitive operations ranging from pushbutton speed to kilocycles. It is possible that under high duty cycles, delay time might be appreciably shortened. This could be due to failure of the capacitors in the multivibrator circuit to discharge completely when triggered at high repetitive rates. The object is to determine the exact decrease in delay time at various speeds.

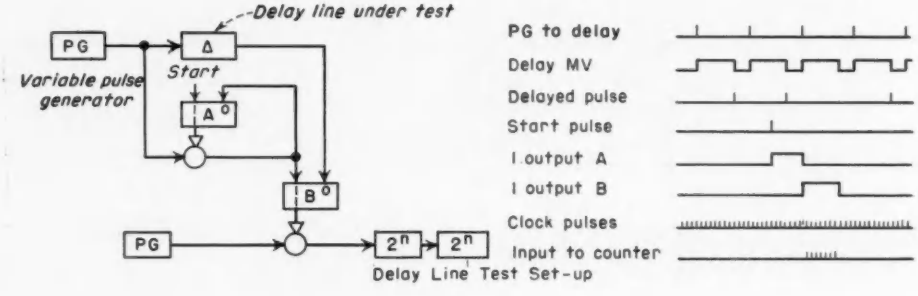
In this test system, a variable frequency pulse generator triggers the delay line under test. A second precision pulse generator supplies a steady stream of fixed frequency pulses that measure the delay

time. The flip-flops are connected to turn the clock pulses on and off at the same time the delay is turned on and off. Counters are added to record the number of clock pulses that occur during the delay interval.

The trick in determining delay time at high frequencies lies in sampling a single delay interval. It can be done this way: the free-running pulse generator delivers a steady stream of pulses that continuously triggers the delay. But since both flip-flops are in their *O* states at the start, neither trigger or clock pulses can get through their respective gates.

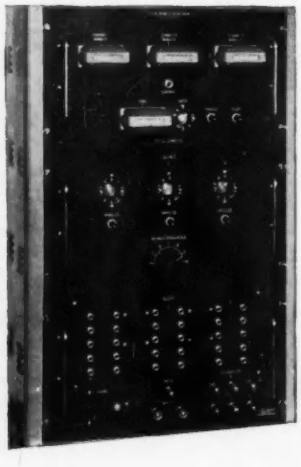
The test begins when a start pulse is fed into the *1* input of flip-flop *A* opening the associated gate. Then the next pulse from the free-running generator passes through the gate of flip-flop *A* in addition to triggering the delay unit. This accomplishes two things. It opens the gate of flip-flop *B* to start clock pulses streaming into the counters. It also resets flip-flop *A* to the *O* state. This keeps the next trigger pulse from getting through.

At the end of the delay interval, the delay unit delivers an output pulse. This closes the gate of flip-flop *B* and stops the flow of clock pulses to the counters. The count of pulses in the two counters then gives an accurate measure of delay time. The delay can be tested at pushbutton rates similarly.



Delay Line Test Set-up

Pulses For Publisher Feedback



No publisher likes wasted newsprint. Before a printing run he decides—by a jealously guarded formula—how many copies he'll need. Then the presses roll. But they often roll so fast that a costly over-run spews off before one can peal "Stop the press."

The three-tier electronic totalizer at the left is the main unit in a system that has solved this problem for a British newspaper publisher. Each of his 24 high-speed paper delivering machines feeding the press is fitted with a photocell pickup to generate a pulse each time a quire of paper goes past. All pulses funnel into the totalizer, which adds up the quires and converts them into bundles of papers. The final relay of the totalizer, which is impulsed once every tenth bundle, supplies a 24-v pulse input over telephone wire to a subtracting counter in the publisher's office. This displays the number of bundles on a 4-decade register and can be pre-set to any figure.

Regally, in his quiet, distant office, the publisher merely twists a knob to stop printing at any total. When the press room nears this figure a bell rings in the overseer's office, providing ample time to close the presses down.

A SYSTEMS ANALYSIS PREDICTS PERFORMANCE

GEORGE J. FIEDLER, THOMAS F. McGRATH, and ADOLPH E. BUESCHER, Sverdrup & Parcel, Inc.

Since its inception, CONTROL ENGINEERING *has counselled engineers and scientists to determine dynamic characteristics before attempting to design control systems. Past articles have described some of the tools for dynamic analysis and how they can be used. This article—a special* CONTROL ENGINEERING *"Methods At Work"—puts the tools to work. It is a complete analysis of a real problem, step-by-step, and with all related computations. Any engineer faced with balancing the costs of control against performance will find this "Methods At Work" a major reference.*

For the reader's convenience this article is divided into two sections—1) the actual system analysis, and 2) at the right on each spread, invaluable background material which will help the reader follow the analysis.

METHODS AT WORK

THE GIST: A complete step-by-step analysis of a pressure control system, before any components are bought, shows how to save on initial cost and still get the performance you need.

Modern methods make it possible to predict the performance of any system of parts. And the relative worth of each part to the system can be weighed against its cost. But for maximum gain from the analysis, none of the parts can be specified beforehand.

Since the "plant" is part of the control system, its design, too, must wait on systems analysis. As it turns out, the plant's tanks and valves have a most important effect on performance—and cost. The controller itself is relatively less important.

Follow the authors through their analysis of this simple pressure system, as they show how several plants can give the same performance, but at far different costs. All the math is here for a complete understanding of the methods; even that which is corollary to the pressure system and only incidental to the control system.

Systems analysis is the best approach to process systems design.

Some analytical work has always been done during the design of a process plant or a power generating plant. This work is now called systems engineering. With simple systems this analytical phase may only involve a mental comparison with previous designs. When systems are complex, however, analysis may consume many man-hours.

Modern mathematical methods make possible a thorough preliminary analysis of proposed processes. Thus the true dynamic character of automatic control systems can be studied before the process components are bought. Economic choice of plant components and controllers can be made while a choice exists: before the equipment has been put under contract.

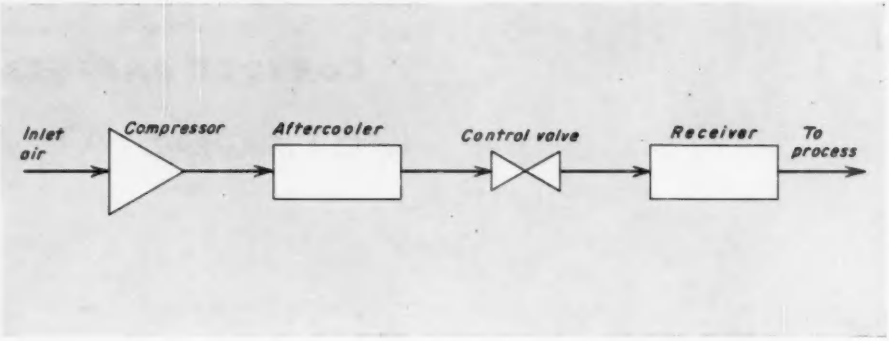
Besides the economic aspects, systems engineering can produce truly compatible specifications for all components. Also, process limitations can be stated more clearly. The problems of starting, running, and shakedown testing can be more organized and efficient, and reserve for future extension of the process and its control system can be planned instead of accidental.

But the most important benefit from systems analysis is the possible economies in initial plant cost. The relation between incremental performance improvement and incremental plant cost can be plotted. Engineers and management then can balance cost and performance.

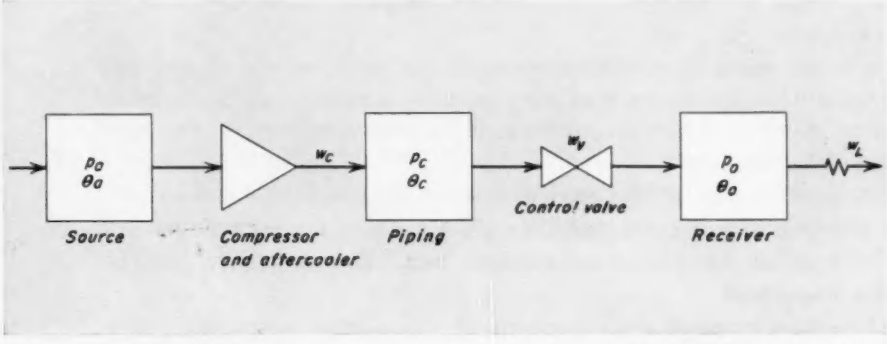
THIS COMPLETE EXAMPLE SHOWS HOW

To show how systems analysis results in plant economy, let's analyze a simple pressure control system. The advantages, of course, are even greater for more complex systems.

The process is a simple air system: a compressor, an after-cooler, and a receiver in which air pressure is to be controlled. The controlled system must



Plant Flow Diagram. FIG. 1



Plant Block Diagram. FIG. 2

provide a source of constant pressure air from the receiver to an external process over a wide range of flow.

I. FLOW DIAGRAM

The first step in the analysis is to draw the plant flow diagram shown in Figure 1. Initial flow diagrams may require modifications as analysis progresses. The control valve location is somewhat arbitrary at this point, as it may be better to control a flow of air that by-passes the receiver and dumps to atmosphere.

II. SYSTEM REQUIREMENTS

The second step is to specify system performance requirements. These depend on the demands of the exterior processes that use the air supply. For this example, the system requirements are:

▶ **Range–**

Pressure–It must be possible to adjust the controlled pressure to any value between 100 psia and 150 psia

Flow–Normal load will be between 10 and 20 lb per sec air flow

▶ **Accuracy**–Receiver pressure must be within 1.0 psi of the set point at all times during normal operation. This accuracy must be maintained for constant flow and for flow changes up to 5 lb/sec²

▶ **Stability**–The system must overcome disturbances and automatically return to steady conditions after the disturbances

III. PLANT BLOCK DIAGRAM

The flow diagram of step I now is expanded to include the effects of piping and auxiliary components. The block diagram thus formed (Figure 2) is very similar to the flow diagram for this simple example. Nomenclature for this latter diagram is listed below:

p_a = atmospheric pressure—lb/ft² absolute (psfa)
θ_a = atmospheric temperature—(deg R)
w_c = compressor air flow—(lb/sec)
p_c = pressure leaving aftercooler—(psfa)
θ_c = temperature leaving aftercooler (deg R)
w_v = valve air flow (lb/sec)
p_o = pressure in receiver (psfa)
θ_o = temperature in receiver (deg R)
w_L = air flow to the process load (lb/sec)

This assumes that the system can be described adequately by three pressures, three temperatures, and three flows. The Reference Section, "Distributed and Lumped Parameters", discusses the justification for this assumption. A forthcoming article will analyze the temperature control of the aftercooler.

IV. CONTROLLED PLANT SYSTEMS ANALYSIS

The objective of the controlled plant systems analysis is to find the minimum-cost system that will just give the specified performance. Plans can be made at this point to extend the range of the system for future expansion. Error and stability equations are studied, so that plant performance also can be known before construction.

To start the plant analysis, develop the equations describing the relationships between components on the block diagram of Figure 2.

Receiver

The weight of air in the receiver depends on the time history of flow to and from the tank. Assuming that the controlled pressure, p_o, is uniform throughout the tank, this relationship is:

$$p_o = \frac{1}{C_o} \int (\text{net flow, lb/sec})\, dt \qquad (1)$$

where Reference Section "Fluid Mechanics of the System" defines C_o— or in Laplace transform notation:

$$P_o = \frac{1}{C_o s} (\text{net flow}) \qquad (2)$$

The net flow to the receiver is the inflow, w_v, minus the outflow, w_L. Using the small perturbation theory, Equation 2 in Laplace notation is:

$$P_o = \frac{1}{C_o s} (W_v - W_L) \qquad (3)$$

Aftercooler and Piping from Compressor to Control Valve

For this volume, the relations are similar to (2) and (3):

$$p_c = \frac{1}{C_c} \int (\text{net flow})\, dt \qquad (4)$$

or

$$P_c = \frac{1}{C_c s} (W_c - W_v) \qquad (5)$$

Control Valve Flow

From basic equations given in Reference Section "Control Valve Characteristics" the weight flow through the control valve can be written as:

$$w_v = \frac{K_1 A p_c F}{\Theta_c^{1/2}} \qquad (6)$$

where A is effective valve area and K_1 and F are defined in Reference "Control Valve Characteristics." Taking the total differential (see Reference "Linearize Non-Linear Equations") and collecting terms:

$$W_v = K_3' P_c + K_4 A + K_5 \Theta_c + K_6' P_o \qquad (7)$$

where the constants are defined by the valve equation and curves for F.

REFERENCE CALCULATIONS

LINEARIZE NON-LINEAR EQUATIONS

Most physical systems do not behave linearly over their operating range; i.e., their behavior cannot be described by any equation in the first degree. But if the range can be decreased sufficiently at each operating point, the equation is approximately linear, and if solved as such, yields results accurate enough for proper selection of control components.

If the dependent function is a linear function of other variables, e.g., if

$$w = f(x, y, z) \qquad (1)$$

where w is the dependent function, the total derivative is

$$dw = \frac{\partial w}{\partial x} dx + \frac{\partial w}{\partial y} dy + \frac{\partial w}{\partial z} dz \qquad (2)$$

Then, at a particular operating point, over a range narrow enough so that the functions are essentially linear, the slope of the curve is constant, so that

$$\frac{\partial w}{\partial x} = K_1, \qquad \frac{\partial w}{\partial y} = K_2, \qquad \frac{\partial w}{\partial z} = K_3$$

Therefore: $dw = K_1\, dx + K_2\, dy + K_3\, dz$

If $dw = W$ and $dx = X$,

$$W_o = K_1 X_o + K_2 Y_o + K_3 Z_o \qquad (3)$$

This linearized equation is good only at the operating point, W_o, defined at X_o, Y_o, and Z_o, and K_1, K_2, and K_3 can be evaluated as the slope of the curve at the operating point, or by analytic partial differentiation.

FLUID MECHANICS OF THE SYSTEM

Resistance, R

The resistance of the system is the resistance to flow or to flow changes. These resistances cause pressure drops in the piping and other flow chambers.

If turbulent flow is assumed through the system, then:

$$\Delta p = p_i - p_o = K w^2 \qquad (1)$$

where

Δp = pressure drop, psfa
p_i = pressure in, psfa
p_o = pressure out, psfa
K = constant of proportionality
w = weight flow, lb/sec

From Equation 1, $p_o = p_i - Kw^2$

Taking the total differential:

$$dp_o = dp_i - 2Kw\,dw \qquad (2)$$

Compressor Flow

Similarly, from basic compressor equations, the weight flow through the compressor is:

$$w_c = \frac{K_2 p_a E}{\theta_a} \tag{8}$$

See Reference "Compressor Analysis" for the compressor flow versus pressure curve, where E is a function of compression ratio, and K_2 is defined. Taking the total differential and collecting terms, we write:

$$W_c = K_7' P_a + K_8 \Theta_a + K_9' P_c \tag{9}$$

Load Flow

The weight flow out of the receiver to the load is:

$$W_L = \frac{P_o}{K_L} \tag{10}$$

K_L is defined in Reference "Evaluation of Constants".

Evaluation of Constants

One set of the constants in the foregoing equations is calculated for each operating point. For systems with a wide operating range, it is usually necessary to evaluate the constants at several operating points. For such wide range systems, one should "map" or plot the value of each constant throughout the operating range.

System Equations to Block Diagram

The "plant" equations are:

$$P_a = \frac{1}{C_a s} (W_v - W_L) \tag{3}$$

$$P_c = \frac{1}{C_c s} (W_c - W_v) \tag{5}$$

$$W_v = K_3' P_c + K_4 A + K_5 \Theta_c + K_6' P_a \tag{7}$$

$$W_c = K_7' P_a + K_8 \Theta_a + K_9' P_c \tag{9}$$

$$W_L = \frac{P_o}{K_L} \tag{10}$$

The plant is described by simultaneous solution of these differential equations.

These expressions describe the dynamic relationship between the controlled variable (receiver pressure) and:

- The action of the final control element (the control valve)
- The disturbance of a change in flow to the external process
- Other disturbances

The control equations now can be added to the plant equations to define the entire system. Then a controller can be synthesized that will meet the system performance requirements. The control system must:

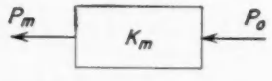
1. Measure the controlled variable P_o
2. Compare it with the set-point value
3. Move the control valve to hold the error within the limits specified

When the flow leaving the receiver is changing, proportional control is needed because valve open area must be proportional to the error in P_o. When the flow leaving the receiver is constant, integral control is needed because the valve open area must be proportional to the integral of the error.

The sensing system output, P_m, must be a signal proportional to pressure:

$$P_m = K_m P_o \tag{11}$$

Equation 11 can be shown in block diagram form as:



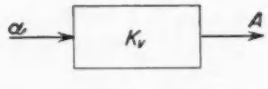
The controller and valve system must be a valve angle, a, proportional to the error plus the integral of the error. The controller transfer function is defined as G_c; the valve transfer function as G_v. The over-all function is therefore $G_c G_v$. An ideal valve transfer function would be $G_v = K_v$ where K_v relates valve position to valve signal V_v. For this problem, we need an over-all (ideal) function:

$$G_c G_v = K \left(K_p + \frac{K_i}{s} \right) \tag{12}$$

where K_p is the over-all adjustment of the proportional factor and K_i is the over-all adjustment of the integral factor. K_i/s is the integral of K_i in Laplace notation.

Suppose a valve so characterized that the shaft position is proportional to open area (linear) is driven by a two-phase motor at a speed proportional to control phase voltage V_v. For a linear valve, valve open area, A, equals a constant, K_v, times valve open angle, a, or:

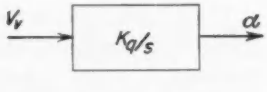
$$A = K_v \alpha \tag{13}$$



The motor shaft angle ideally is proportional to the integral of the motor control phase voltage,

$$\alpha = \frac{K_q}{s} V_v \tag{14}$$

or:



The ideal function for the valve and controller is given by Equation 12. For the ideal valve system transfer function, combine Equations 13 and 14,

$$G_v = \frac{K_q}{s} K_v \tag{15}$$

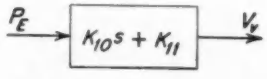
G_c can now be derived from Equation 12 and Equation 15,

$$G_c = \frac{G_c G_v}{G_v} = K \frac{\left(K_p + \frac{K_i}{s}\right)}{\frac{K_q}{s} K_v}$$

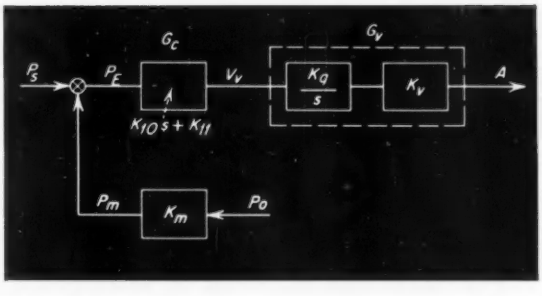
$$= \frac{KK_p s + KK_i}{K_q K_v} = \frac{KK_p}{K_q K_v} s + \frac{KK_i}{K_q K_v}$$

$$= K_{10} s + K_{11} \qquad (16)$$

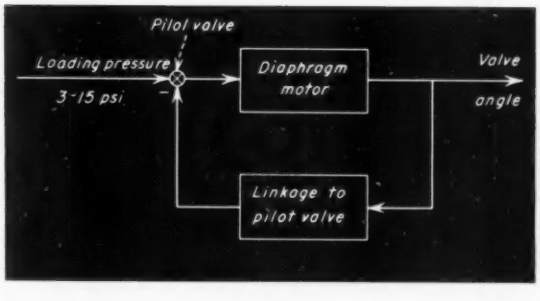
Or:



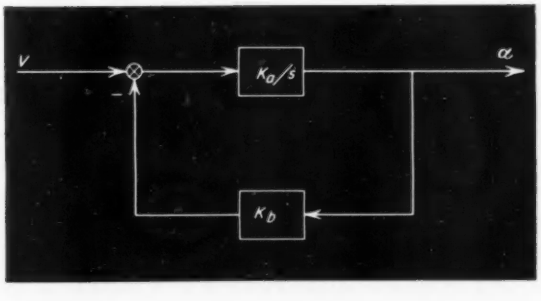
Combining the foregoing in block form, the control system for the plant now looks like this:



If a standard pneumatic valve positioner were used, valve position would always correspond to the signal from the controller. This is done by internal feedback within the positioner:



Or:



REFERENCE CALCULATIONS

Also from Equation 1:

$$Kw = \frac{\Delta p}{w} \qquad (3)$$

placing Equation 3 in Equation 2,

$$dp_o = dp_i - \frac{2\Delta p}{w} dw$$

Linearizing and writing in Laplace notation

$$P_o = P_i - 2 \frac{(\Delta P_o)}{W_o} W_o$$

$$\text{or } P_o = P_i - RW_o \qquad (4)$$

where R is the incremental flow resistance at the operating point in psf/lb/sec.

Inertance, L

The fluid inertance is the applied pressure required to accelerate unit fluid weight. Consider a flow path of constant cross section, A, and length, X, carrying air at a rate of w lbs/sec, and being accelerated at a rate of dw/dt lbs/sec^2. The density, ρ, of the gas, according to the perfect gas law, is:

$$\rho = \frac{p}{R\theta} \text{ in lb/ft}^3 \qquad (5)$$

where

R = gas constant, 53.3 ft per deg,
θ = temperature, deg R.

The quantity flow will be:

$$Q = \frac{w}{\rho} \text{ in ft}^3\text{/sec} \qquad (6)$$

Assuming uniform velocity over the piping cross section,

$$v = \frac{Q}{A} = \frac{w}{\rho A} \text{ in ft/sec} \qquad (7)$$

The acceleration assuming constant pressure is

$$a = \frac{dv}{dt} = \frac{1}{\rho A} \frac{dw}{dt} \text{ in ft/sec}^2 \qquad (8)$$

The mass of air is

$$m = \frac{\rho A x}{g} \text{ slug-ft}^3 \qquad (9)$$

The accelerating force in pounds is

$$F = ma = \frac{x}{g} \frac{dw}{dt} \qquad (10)$$

The force per unit area is provided by a pressure difference; hence:

$$\frac{F}{A} = \frac{x}{Ag} \frac{dw}{dt} = L \frac{dw}{dt} \text{ psf} \qquad (11)$$

where $L = \frac{x}{Ag}$ in psf/lb/sec^2

Capacitance, C

Capacitance is the parameter of a flow system

Where K_a and K_b are valve constants.
Then

$$\frac{\alpha}{V} = \frac{\frac{1}{K_b}}{\frac{1}{K_a K_b}s + 1} = \frac{K_q}{\tau_q s + 1} \tag{17}$$

In this event, the controller requirement would have been $K + K/s$, the same as the over-all function from error to valve area.

Actual valves, valve positioners and sensing systems have dynamic characteristics that differ from their static characteristics. If the signal to the valve changes slowly, the valve follows the signal closely. If the signal changes rapidly, the actual valve position lags farther behind the signal. This lag or phase shift is a function of many of the physical characteristics of the valve, such as inertia, damping, etc. As shown in Reference "Control Valve Characteristics", a physical valve may be described in simplified terms by:

$$G_v = \frac{K_q K_v}{s(\tau_q s + 1)} \tag{18}$$

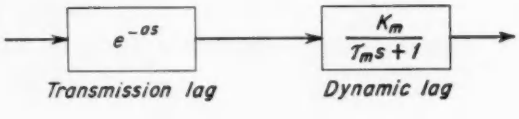
where τ_q is the valve time constant.

A sensing system has two kinds of lags:

▶ **Transmission lag**–Time required for the signal to travel. In pneumatic sensing, the signal travels with the speed of sound; in electric transmission, with the speed of light (approx.).

▶ **Dynamic lag**–Time needed to accelerate physical inertias in the system.

A physical sensing system having these two lags has this block diagram:



Computation of Component Requirements

The relation of a change in control valve position to a change in receiver pressure can be written from the system equations. These relationships also can be obtained from the complete block diagram, Figure 3. Combining Equations 3, 7, and 10, or combining appropriate blocks in the diagram, we write this relationship as:

$$\frac{P_o}{W_x} = -\frac{\frac{K_L}{1 - K_L K_6'}}{\left[\frac{K_L C_o}{1 - K_L K_6'}\right]s + 1} \tag{19}$$

$$= -G_p \text{ by definition.}$$

and:

$$\frac{P_o}{A_v} = K_4 G_p \tag{20}$$

We may also immediately relate the effect of P_c and Θ_c on P_o by the following:

$$\frac{P_o}{P_c} = K_3' G_p \tag{21}$$

The effect of the P_c function will be discussed later.

$$\frac{P_o}{\Theta_c} = K_5 G_p \tag{22}$$

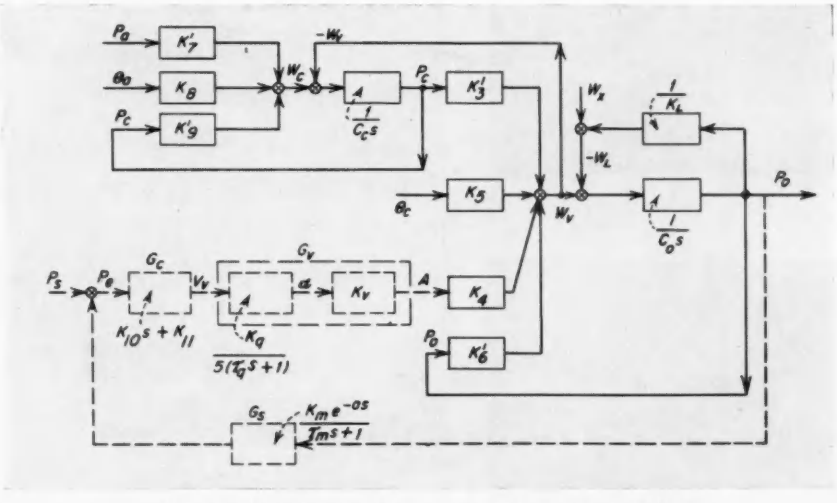
The temperature of the air leaving the aftercooler will be held constant by a temperature control system; therefore Θ_c is assumed zero.

From the combined plant and controller equations, the relation of receiver pressure, P_o, to the set-point pressure, P_s, can be written. The pressure error is the difference,

$$P_e = P_s - P_o \tag{23}$$

The ratio P_o/P_s may be found algebraically by first writing:

$$\frac{P_o}{P_e} = G_c G_v K_4 G_p \tag{24}$$



Complete block diagram for pressure control system. FIG. 3

$$= \frac{(K_{10}s + K_{11})K_qK_vK_4}{s(\tau_q s + 1)} G_p \qquad (25)$$

$= G_o$ by definition

then:

$$\frac{P_o}{P_s} = \frac{G_o}{1 + G_oG_s} = \frac{G_o}{1 + G_o \dfrac{K_m e^{-as}}{\tau_m s + 1}}$$

P_e is related to $-W_x$, for a constant set-point, by:

$$\left.\frac{P_e}{-W_x}\right]_{P_s=0} = \frac{G_p}{1 + G_pG_sG_cG_vK_4} \qquad (26)$$

To write an explicit expression for P_e, first note that when p_s is not changing, $P_s = 0$ and $P_o = P_e$. Also, note that W_x is the transform of the time function

$$w_L = f(t) = mt$$

where $m = 5$ psi/sec² from the plant operating requirements. The requirement was that the error must be less than 1 psi during the 5 psi/sec² change in flow. Since w_L is a function of time,

$$w_L = mt \qquad (27)$$

By definition, W is the Laplace transform of w. The Laplace transform of t from standard transform tables is $1/s^2$. Since m is a constant,

$$W = \frac{m}{s^2} \qquad (28)$$

Combining Equation 26 and 28,

$$P_e = \frac{\dfrac{m}{s^2} G_p}{1 + G_pG_sG_cG_vK_4}$$

From the Final Value Theorem of operational calculus, i.e.,

$$sF(s)\,|_{s\to 0} = f(t)\,|_{t\to\infty} \qquad (29)$$

the final value of P_o is:

$$sP_o = \frac{\dfrac{K_p m}{s(\tau_p s + 1)}}{\dfrac{1 + K_pK_mK_{11}K_qK_vK_4e^{-as}(\tau_c s + 1)}{s(\tau_m s + 1)(\tau_q s + 1)}}$$

$$= \frac{m}{K_mK_{11}(K_qK_vK_4)} \qquad (30)$$

Accuracy and Stability Calculations

To satisfy the other requirement that the error be small when the load flow w_L is constant, note that:

$$sP_o\,|_{s\to 0} = 0 \qquad (31)$$

or the error theoretically is zero for constant load.

Knowing the combination of constants to produce the required performance, i.e.,

$$\frac{m}{K_mK_{11}K_qK_vK_4} = 144 \text{ psf} = 1 \text{ psi} \qquad (32)$$

the system can be adjusted accordingly to control within the allowable error.

The system must also be stable when adjusted for allowable error. A closed-loop system will

REFERENCE CALCULATIONS

required by the law of conservation of energy because inflow does not equal outflow due to compressibility.

From the equation of state for perfect gases, the weight flow, w, can be written:

$$w = \frac{pv}{R\theta} \text{ where } v = \text{volume in ft}^3 \qquad (12)$$

Weight flow rate of change is the difference between inflow and outflow:

$$\frac{dw}{dt} = w_i - w_o = \frac{v}{R\theta}\frac{dp}{dt} - \frac{pv}{R}\frac{1}{\theta^2}\frac{d\theta}{dt}$$

or:

$$w_i - w_o = \frac{v}{R\theta}\left[\frac{dp}{dt} - \frac{p}{\theta}\frac{d\theta}{dt}\right] \qquad (13)$$

If the process is assumed adiabatic,

$$\frac{d\theta}{\theta} = \frac{\gamma - 1}{\gamma}\frac{dp}{p} \qquad (14)$$

where γ = ratio of specific heats
Substituting in Equation 13:

$$w_i - w_o = \frac{v}{R\theta_o}\left[\frac{dp}{dt} - \frac{\gamma - 1}{\gamma}\frac{dp}{dt}\right]$$

$$= \frac{v}{\gamma R\theta_o}\frac{dp}{dt}$$

θ_o is the temperature at the operating point only, or

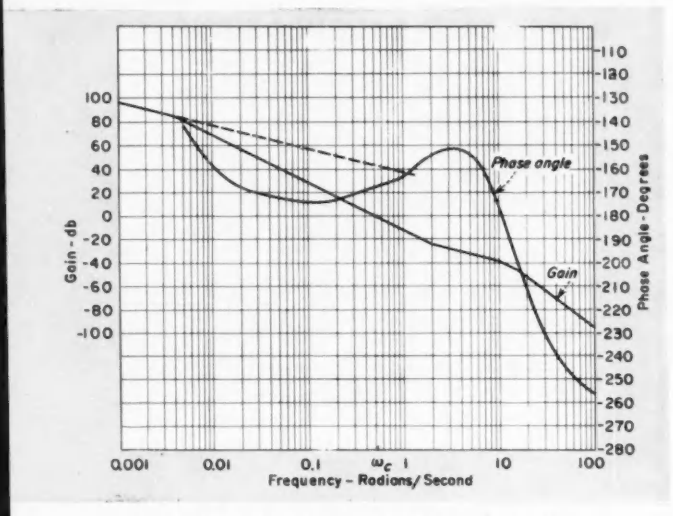
$$w_i - w_o = C_o\frac{dp}{dt} \qquad (15)$$

where: C_o is the system capacitance in lbs per/psf and $C_o = \dfrac{v}{\gamma R\theta_o}$ is the capacitance of the receiver.

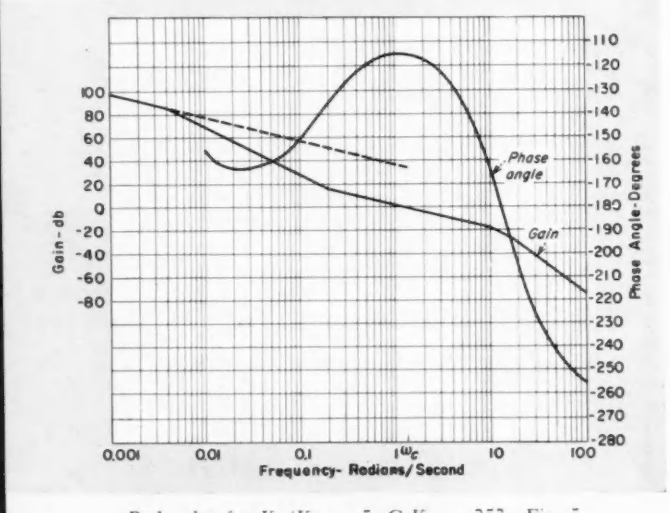
DISTRIBUTED AND LUMPED PARAMETERS

In piping, the three parameters, R, L, and C, relate flow to pressure. These parameters are functions of length of the piping, and of time. In linearizing they are treated as functions of time. They can be considered also as functions of space. Then, instead of L, R, and C, they become $L/$ unit length, $R/$ unit length, etc., and are called distributed constants.

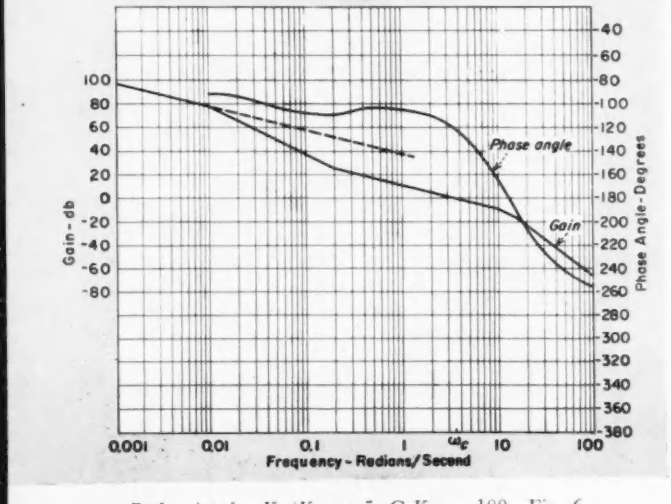
Where a very accurate analysis is necessary, it is possible to distribute parameters using wave equations with partial spatial derivatives. Generally, this accuracy is not required, and the parameters may be lumped over small distances. This is enough for systems analysis. For example, a long pipe may be analyzed as five capacities, resistances, and inductances, rather than as one. This may be almost as accurate as using the wave equations.



Bode plot for $K_{10}/K_{11} = 0.5$, $C_0K_L = 253$. Fig. 4



Bode plot for $K_{10}/K_{11} = 5$, $C_0K_L = 253$. Fig. 5



Bode p'ot for $K_{10}/K_{11} = 5$, $C_0K_L = 100$. Fig. 6

oscillate continually if the loop transfer function has a phase shift of 180 deg and the loop gain is unity. The degree of stability can be found from a Bode plot of the loop function—magnitude and phase shift versus frequency—and is a function of the time required for oscillations to damp out.

To show how to calculate the accuracy and stability of this system, the constants are evaluated at one operating point in Reference "Evaluation of Constants". At this operating point:

$$G_p = \frac{2112}{253s + 1} \quad \frac{\text{lb/ft}^2}{\text{lb/sec}} \tag{33}$$

$$K_4 = 2420 \text{ lb/sec-ft}^2 \tag{34}$$

$$G_v = \frac{(1.8 \text{ deg/volt-sec})(0.00308 \text{ ft}^2\text{/deg})}{s(0.1s + 1)} \tag{35}$$

$$G_s = \frac{0.001 \text{ volts/psf}}{0.06s + 1} \tag{36}$$

and

$$G_c = K_{11}\left(\frac{K_{10}}{K_{11}}s + 1\right)$$

From the formula for error, the value of $K_4\ K_v\ K_q\ K_{11}\ K_m$ must equal or be greater than $m/144$ to meet the accuracy requirements of the system. Since each constant is known except K_{11}, first solve for K_{11} and use it to check stability on the Bode diagram. The Bode diagram shown on Figure 4 is a plot of the function $G_s\ G_c\ G_v\ K_4\ G_p$ versus frequency on semi-log paper. The log scale presents an easy way to plot the product of several functions, since multiplication here means merely adding logarithms.

The ratio K_{10}/K_{11} was chosen as 0.5 for a first trial value. On Figure 4, the magnitude curve crosses the unity line (zero db) at a frequency of 0.55 radians per second. This system is stable because the phase shift at this frequency and all lower frequencies (gain greater than unity) is less than 180 deg. The maximum phase shift up to the "crossover" frequency (0.55 rad/sec) is −174 deg. The phase margin is, therefore, 180–174 or 6 deg, a very small amount, indicating a small degree of stability. Good design would provide a margin of something like 35 deg.

The first trial value for K_{10}, resulting in the K_{10}/K_{11} ratio equal to 0.5, might improve the situation if changed. If this ratio is made 5 instead of 0.5, the crossover frequency changes and the phase shift is considerably reduced, increasing the phase margin. See Figure 5.

The components that cause the phase shift should be noted, remembering also that the degree of stability puts a ceiling upon accuracy. If phase margin is increased, the value of K_{11} can be increased. This increases the accuracy without causing instability. In this system, the phase shift is mostly due to two components, the valve actuator system and the "plant" function, dominated by receiver volume.

If the receiver volume were smaller, the phase shift

would be reduced. How much smaller should it be? This now can be decided readily. If we are satisfied with the 1.0 psi error in P_o, the plant time constant could be reduced, changing the crossover frequency and the phase shift, taking care not to increase the crossover frequency to a point where the phase shift is greater than 180 deg.

Suppose the plant time constant were 100. Then:

$$C_v K_L = 100 \tag{37}$$

or

$$C_v = \frac{100}{(2112)} = 0.0474$$

$$v = C_v R\theta = (0.0474)(53.35)(560) = 1{,}410 \text{ ft}^3$$

See Figure 6.

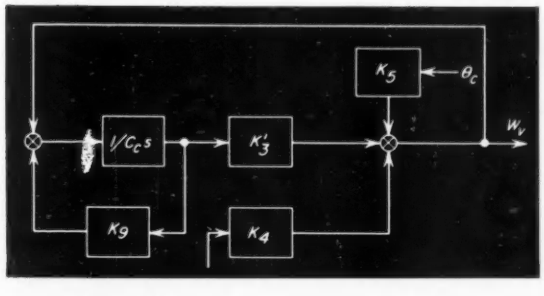
The valve system could be improved by adding feedback of the pneumatic positioner type.

The valve time constant, which is a measure of the response of the valve positioner, is such that it does not reduce the stability of the system at all. The same may be said of the sensing system.

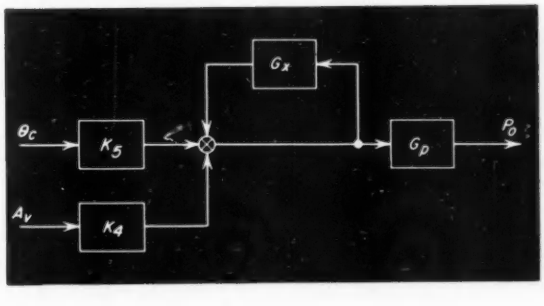
Effect of the Compressor Characteristic

The effect of the compressor characteristic can be introduced by referring to Figure 3 and adding the compressor functions to the equations. The compressor functions, K_7', K_8 and K_9', and the piping and aftercooler characteristics, $1/C_c s$, act on the "plant" through the valve function, K_3'.

Assuming atmospheric pressure constant, ($dp_a = P_a = 0$), and atmospheric temperature constant ($d\theta_a = \Theta_a = 0$), then K_7' and K_8 can be neglected, giving



from which follows:



REFERENCE CALCULATIONS

COMPRESSOR ANALYSIS

The centrifugal compressor was selected for its high compression ratio. It runs at a single constant speed. While the flow is limited, it is adequate for the process. Reciprocating machines were considered and discarded, since oil-free air is necessary, and non-lubricated machines of the reciprocating type are relatively expensive.

The weight flow of air through the compressor is the product of inlet density and inlet volume flow,

$$w_c = \rho_a v_a = \frac{p_a}{R\theta_a} f_c\left(\frac{p_c}{p_a}\right) \tag{1}$$

where $\rho_a = \frac{p_a}{R\theta_a}$, inlet air density lb/ft³

$v_a = f_c\left(\frac{p_c}{p_a}\right)$, inlet volume flow ft³/sec

and w_c is a function of the variables p_a, θ_a, and f_c, i.e.,

$$w_c = f(p_a, \theta_a, f_c)$$

Taking the total differential,

$$dw_c = \frac{\partial w_c}{\partial p_a} dp_a + \frac{\partial w_c}{\partial \theta_a} d_a\Theta + \frac{\partial w_c}{\partial f_c} df_c \tag{2}$$

Since $f_c = f(p_a, p_c)$,

$$df_c = \frac{\partial f_c}{\partial p_a} dp_a + \frac{\partial f_c}{\partial p_c} dp_c \tag{3}$$

Substituting Equation 3 in Equation 2, and using the linearizing techniques for an incremental change,

$$W_c = K_7 P_a + K_8\Theta_a + K_9(K_{9a}\Theta_a P_a + K_{9b}P_c) \tag{4}$$

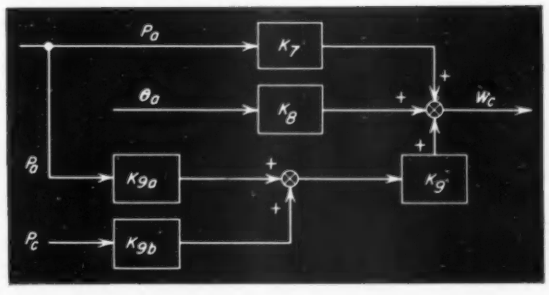
or

$$W_c = K_7' P_a + K_8\Theta_a + K_9' P_c$$

where

$$K_7' = K_7 + K_9 K_{9a} \quad \text{and} \quad K_9' = K_9 K_{9b}$$

Equation 4 can be shown in block diagram form as:



Equation 4 is written for changes at a specific operating point. If the compressor input is from atmosphere, p_a and θ_a are constant. Therefore,

where:

$$G_x = \frac{K_3'/K_9'}{\left(\frac{C_e}{K_9'}\right)s + 1}$$

Assuming θ_e constant, the new relationship between P_o and A_v is:

$$\frac{P_o}{A_v} = \frac{K_4 G_p}{1 + G_x} \tag{38}$$

Note that this function, with the compressor included, differs from Equation 20 for $\frac{P_o}{A_v}$ by the factor $\frac{1}{1 + G_x}$.

When $\frac{1}{1 + G_x}$ is evaluated numerically at the operating point,

$K_3' = 5.27 \times 10^{-4}$, $K_9' = 0.022$, and $C_e = 0.024$

Substituting these values:

$$G_x = \frac{0.0239}{1.09s + 1}$$

and:

$$1 + G_x = \frac{1.0239(1.065s + 1)}{1.09s + 1} \approx 1 \tag{39}$$

Numerically, Equation 39 has little effect on the Bode diagram. G_p is virtually equal to $\frac{G_p}{1 + G_x}$.

The compressor characteristic $\left(w_c = f\frac{P_c}{P_a}\right)$ shows that, at the operating point, large changes in flow cause only small changes in compression ratio, i.e., the curve is flat. For the system requirements and the compressor selected, throttle valve control is good. But for compressors with vertical compressor curves, by-pass control would be best.

COST VERSUS PERFORMANCE

To show all economic aspects of the design and selection of components, performance must be related to cost. The cost of the system is the sum of the cost of plant and control components plus the cost of assembly.

The choice of a centrifugal compressor based on cost savings is discussed in Reference "Compressor Analysis". The aftercooler, valve, and piping are not significant in their effect on over-all system performance and are, therefore, omitted in our cost comparison.

Table I lists relative prices for the components which directly affect system performance. The costs of components originally selected to give required system performance are shown in column 1 of Table I.

Systems analysis showed that the valve actuator and sensing system chosen were better than necessary. It showed also that the receiver was larger than necessary. (See Figure 6). Keeping the same valve actuator permits a greater reduction in the receiver volume and, hence, cost. Column 2, Table I lists new costs for a much smaller receiver and a cheaper sensing system that still give the required system performance.

Now assume that it is desired to determine the cost of a system having the same operating range and the same disturbance magnitude, but twice the accuracy; i.e., 0.5 psi maximum error in receiver pressure. The following product must double; therefore

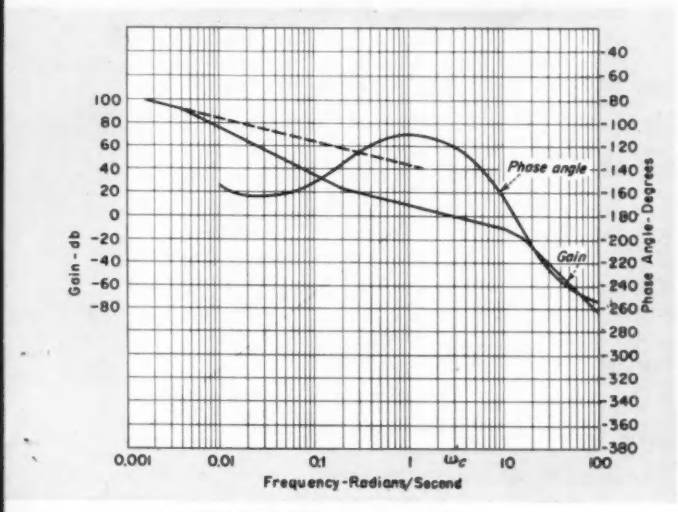
$$K_{11}K_mK_qK_vK_4 = 2(0.0347) = 0.0694 \text{ (Figure 7)}$$

Equipment prices for this higher performance are shown in column 3, Table I. The accuracy improvement is shown to cost \$7,000, or \$11,600 minus \$4,600. Similar methods can show incremental costs due to changes in other performance parameters.

As demonstrated by this example, a systems analysis of the complete system usually will result in lower cost of both plant and control components with no reduction in over-all performance. It is, therefore, highly rewarding to analyze the controlled performance of a proposed facility before final design of the "plant" components or the controllers. The engineering cost of such a complete systems analysis is usually a small percentage of the savings effected in cost of plant and controller components.

TABLE I

	No. 1	No. 2	No. 3
Receiver	\$10,000	\$3,000	\$10,000
Valve Actuator	900	900	900
Controller	600	600	600
Sensing System	400	100	100
TOTAL—	\$11,900	\$4,600	\$11,600



Bode plot for double accuracy. Fig. 7

ACKNOWLEDGEMENT. The techniques used in this paper are not original with the authors. The servo theory and mathematical treatment used is found in books and technical papers too numerous to acknowledge here.

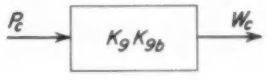
(This column concludes the systems analysis. The Reference Calculations are continued on the following two pages.)

REFERENCE CALCULATIONS

Equation 4 for the change in W_c can be simplified to

$$W_c = K_g K_{gb} P_c \qquad (5)$$

Equation 5 in block diagram form becomes:



where K_g is $\left(\frac{\partial w_c}{\partial f_c}\right)_a$ and K_{gb} is: $\left(\frac{\partial f_c}{\partial p_c}\right)_a$

The product $K_g K_{gb}$ is the slope of Figure R-1 at the operating point.

CONTROL VALVE CHARACTERISTICS

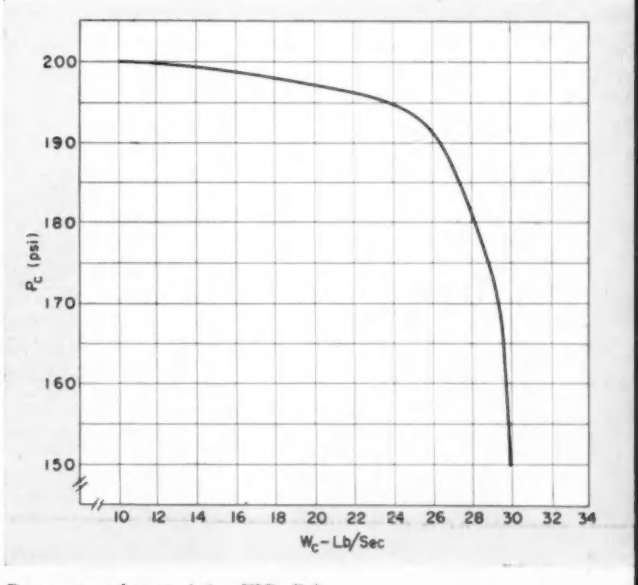
Flow Characteristics

An equation for air flow through a control valve has been found empirically as the result of a research program conducted by the University of Michigan for Sverdrup & Parcel, Inc. This equation is:

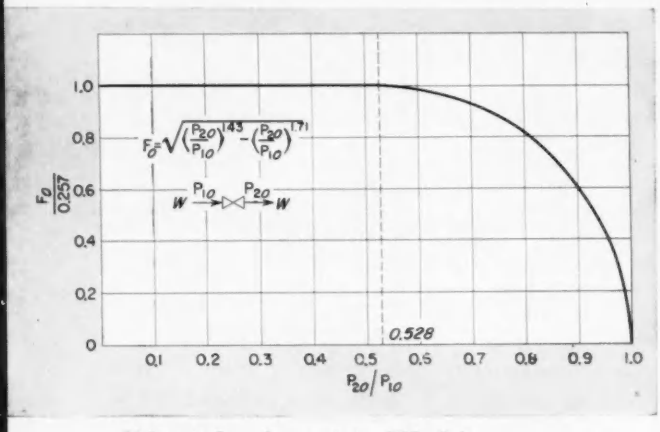
$$w_c = \frac{2.055 a p_1}{\theta} \sqrt{\left(\frac{p_2}{p_1}\right)^{1.43} - \left(\frac{p_2}{p_1}\right)^{1.71}} \qquad (1)$$

or

$$w_c = \frac{2.055 a p_1}{\theta^{1/2}} f_c$$



Compressor characteristic. FIG. R-1



Valve air flow characteristic. FIG. R-2

where a = the valve open area, ft²
p_1 = the upstream pressure, psfa
p_2 = the downstream pressure, psfa
θ = upstream total temperature, deg R
f_v = a function of pressure ratio

From the linearizing procedure

$$w_c = f(a, p_1, \theta, f_v)$$

we can write

$$W_c = K_4 A + K_3 P_1 + K_5 \Theta + K_6 F \qquad (2)$$

And since f_v is a function of the pressure ratio across the valve

$$F = K_{6a} P_1 + K_{6b} P_2 \qquad (3)$$

where $f = 0.257\ F$ to normalize the curve for convenience in computing.

From Equations 1, 2, and 3, we can evaluate the following constants, where the subscript o denotes a particular value computed at each operating point:

$$K_3 = \left|\frac{\partial w_v}{\partial p_1}\right|_o = \frac{2.055 A_o F_o}{\theta_o^{1/2}}$$

$$K_4 = \left|\frac{\partial w_v}{\partial a}\right|_o = \frac{2.055 p_{1o} F_o}{\theta_o^{1/2}}$$

$$K_5 = \left|\frac{\partial w_v}{\partial \theta}\right|_o = \frac{-2.055 A_o P_{1o} F_o}{2\theta_o^{3/2}}$$

$$K_6 = \left|\frac{\partial w_v}{\partial f_v}\right|_o = \frac{-2.055 A_o P_{1o}}{\theta_o^{1/2}}$$

$$K_{6a} = \left|\frac{\partial f_v}{\partial p_1}\right|_o = \frac{-\left[1.43\left(\frac{P_{2o}}{P_{1o}}\right)^{1.43} - 1.71\left(\frac{P_{2o}}{P_{1o}}\right)^{1.71}\right]}{2F_o P_{1o}}$$

$$K_{6b} = \left|\frac{\partial f_v}{\partial p_2}\right|_o = \frac{1.43\left(\frac{P_{2o}}{P_{1o}}\right)^{1.43} - 1.71\left(\frac{P_{2o}}{P_{1o}}\right)^{1.71}}{2F_o P_{2o}}$$

$K_6' = K_6 K_{6b}$
$K_3' = K_3 + K_6 K_{6a}$

These constants are evaluated in Reference "Evaluation of Constants . . ." A plot of F_o versus $\frac{P_{2o}}{P_{1o}}$ is shown as Figure R-2.

Control Valve Sizing

The size of the control valve needed for the system was found from Equation 1. A four-inch double-seated valve has both adequate flow and sufficient pressure drop across the valve for control through the desired range. Standard sizing methods were used. The selected valve has about 8 sq in. of effective area (0.0554 ft²).

Valve Servo System Requirements

The block diagram of the system is:

K_v is a linkage constant that translates driving motor shaft rotation into area. The motor moves through 180 deg to change the area from 0 to 0.0554 sq ft, therefore, $K_v = 0.00308$ sq ft per deg.

The drive motor transfer function is

$$\frac{K_q}{s(1 + \tau_q s)}$$

This transfer function is described in several standard servo texts. K_q is the generator constant in volts per degree per second of the rotor, and τ_q is the time constant of the motor and load in seconds. Evaluation of these constants also is demonstrated in "Evaluation of Constants . . ."

EVALUATION OF CONSTANTS AT THE OPERATING CONDITIONS

The selected operating conditions are at a weight flow of 15 lb/sec, a pressure of 125 psia and a compressor outlet temperature of 100 deg F.

▶ Receiver Capacitance

From "Fluid Mechanics of the System",

$$C_o = \frac{V}{\gamma R \theta_o}$$

The receiver is initially assumed to be a 5,000 cu ft tank, $\gamma = 1.4$, $R = 53.3$ ft/deg, and $\theta_o = 560$ deg R. Substituting these values, $C_o = 0.12$ lb/psf.

REFERENCE CALCULATIONS

▸ Aftercooler Capacitance

The piping and aftercooler are assumed to have a 1,000 cu ft volume. Substituting values,

$$C_c = 0.024 \text{ lb/psf}$$

▸ Control Valve Constants

$$P_o = 125 \text{ psia} = 18{,}000 \text{ psfa}$$
$$\theta_c = 100 \text{ deg F} = 560 \text{ deg R}$$
$$W_v = 15 \text{ lb/sec}$$
$$P_c = 199 \text{ psia} = 28{,}650 \text{ psfa}$$
$$A = 0.0062 \text{ ft}^2$$

$W_v = K_3' P_c + K_4 A + K_5 \Theta_c + K_6' P_o$, the equation for weight flow through the valve. From "Control Valve Characteristics", the valve constants at the operating conditions are:

$$K_3' = \left(\frac{\partial w_v}{\partial p_c}\right)_o + \left(\frac{\partial w_v}{\partial f_v}\right)_o \left(\frac{\partial f_v}{\partial p_c}\right)_o = 5.27 \times 10^{-4}$$

$$K_4 = \left(\frac{\partial w_v}{\partial a_v}\right)_o = 2{,}420$$

$$K_5 = \left(\frac{\partial w_v}{\partial \theta_c}\right)_o = -1.33 \times 10^{-2}$$

$$K_6' = \left(\frac{\partial w_v}{\partial f_v}\right)_o \left(\frac{\partial f_v}{\partial p_2}\right)_o = 1.59 \times 10^{-5}$$

▸ Valve Motor Drive Constants

K_q was selected initially on the basis that 100v would move the valve from closed to full open area in one second. The motor and gears must turn 180 deg; hence, $K_q = 1.8$ deg/volt-sec. K_v is 0.00308 (see "Control Valve Characteristics").

Initial choice of a valve speed favored a 10 radians per sec valve; therefore, the time constant, $\tau_q = 0.1$ sec.

▸ Sensing System

The sensing transfer function, K_m, is selected to cover the output pressure range from 14,400 psfa to 21,600 psfa. The value of K_m is selected initially as 0.001 v per psfa, to give a maximum voltage output of 7.2 v for 150 psia, and a minimum of 0 v at 100 psia. Some overlap is necessary, of course, and can be provided as the design progresses.

One of the better commercial pressure measuring instruments was selected tentatively for the sensing element. $\tau_m = 0.06$ sec.

▸ Compressor Constants

The value of K_9' is found from the slope of the curve at the operating point on Figure R-2 ("Compressor Analysis").

$$K_9' = 0.022 \frac{\text{lb/sec}}{\text{psfa}}$$

▸ Load Constant

The load is the permissible flow change for the system. The incremental flow resistance, R, is defined as the resistance per unit change in flow at the operating point. The characteristic is assumed linear for small perturbations at the operating point.

From "Fluid Mechanics of the System",

$$R = K_L = 2\left(\frac{\Delta P_o}{w_o}\right) \frac{\text{psf}}{\text{lb/sec}}$$

At the selected operating conditions

$$w_o = 15 \text{ lb/sec}, \qquad P_o = 110 \text{ psia}$$

$$K_L = 2{,}112 \frac{\text{psf}}{\text{lb/sec}}$$

◆◆◆◆◆

This analysis assumes that the temperature of the air leaving the aftercooler is constant. As noted on page 68, a future article will analyze the heat exchanger dynamics and their effects on the pressure system.

GEORGE FIEDLER, top man in Sverdup & Parcel's Controls & Instrumentation Section, got his MME from University of Kansas in 1932. Taught EE at four colleges, last as Associate Professor at the University of California, Berkeley. Ran the circuit design section of the Navy's electronics laboratory in San Diego from 1944 to '46. With S&P since.

TOM McGRATH, in the control business since his college days at St. Mary's University in Texas in the '40's, has been an instrument engineer for Goodrich Chemical and Blaw-Knox, and Chief Instrument Engineer for Pine Bluff Arsenal. Got master's from St. Louis University in 1948. Senior Engineer with S&P since 1953.

ADOLPH BUESCHER, a Missourian, got his B.S. in ME from the University of Missouri in 1946, his master's from Stanford in 1950. Has worked on power plant and process control system development for Eastman Kodak, and missile instrumentation and control for Northrop. Joined S&P's Controls & Instrumentation Section in 1953.

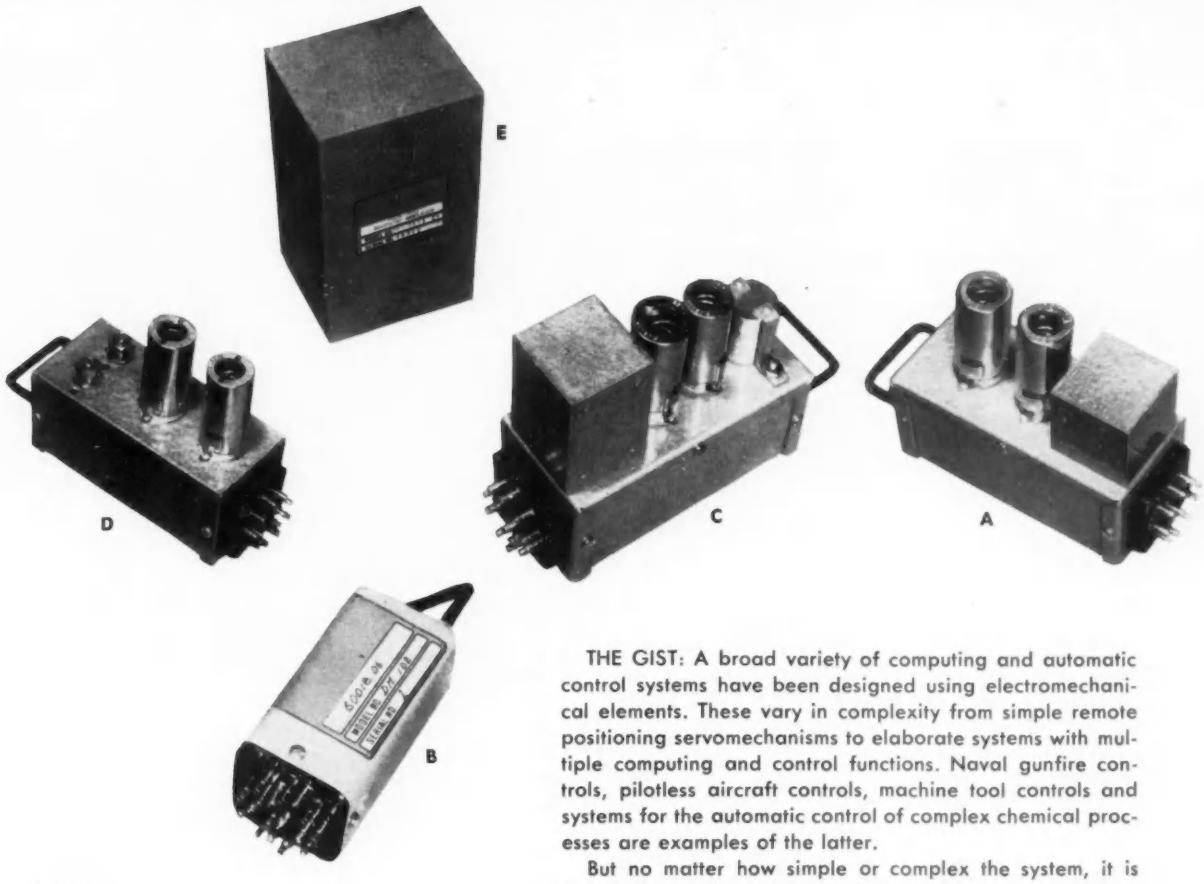


FIG. 1

(A)—Isolation amplifier.
(B)—Phase detector.
(C)—Gain compensating amplifier.
(D)—Dual channel dc amplifier.
(E)—Fifty watt magnetic amplifier.

THE GIST: A broad variety of computing and automatic control systems have been designed using electromechanical elements. These vary in complexity from simple remote positioning servomechanisms to elaborate systems with multiple computing and control functions. Naval gunfire controls, pilotless aircraft controls, machine tool controls and systems for the automatic control of complex chemical processes are examples of the latter.

But no matter how simple or complex the system, it is easier to assemble it from available packaged components than to start designing from scratch. Standardized mechanical and electromechanical components have been on the market for some time. Now functional electrical and electronic packages are appearing. By using five of these packaged functions, plus mechanical and electromechanical components, many very useful control systems can be designed. Here are the details of these functions and examples which show how they can be applied.

NOW YOU CAN Design With Packaged Components

BARNEY J. O'NEILL, Magnetic Amplifiers, Inc.

Savings in time and cost are possible advantages in designing around packaged units. The designer can emphasize the overall system and its performance. A breadboard or prototype system can be assembled quickly and tested with a minimum of time-consuming circuit design.

Production economics are also realized when packaged units are used. Assembly and wiring become simple. So does testing and trouble shooting. These operations can be reduced to routine procedures handled by relatively unskilled personnel.

Maintenance and trouble shooting operations in the field are easier. Faulty plug-in units can be replaced with a minimum loss of operating time.

The defective unit can be discarded, or repaired when convenient. In addition, packaged circuit elements that already have been field tested enhance the reliability of a system.

In standardizing and packaging the functions of an electromechanical computer or control system, the basic elements fall into three classifications.

1. mechanical
2. electromechanical
3. electrical and electronic

The mechanical elements include such items as gears and gear assemblies, cams, mechanical computing linkages, slip clutches, and dials. Many manufacturers offer extensive selections of these devices. In most applications, electromechanical equipment can be designed so that the use of special mechanical elements is limited to a small number of specialized functions.

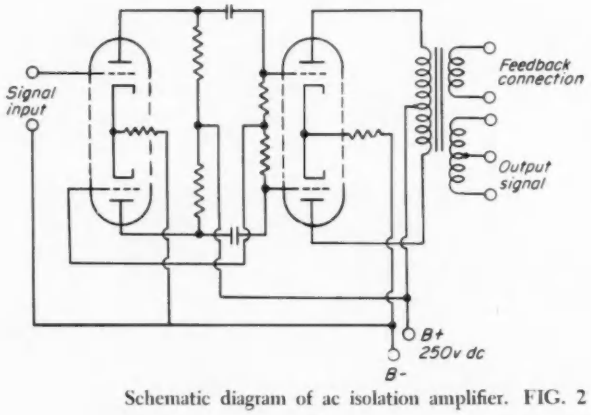
The electromechanical elements common in computer and control systems include servo motors, synchros, resolvers, resistance potentiometers, induction potentiometers and tachometer generators. These devices are available in many ratings and accuracies. Many aspects of their mechanical and electrical design have been standardized so that different makes often can be used interchangeably. Rarely is there a real need for a specially designed item of this type in an analog computer or instrument servo system.

A look at the electrical and electronic elements of a computer or control system reveals that these units vary in an almost infinite number of details. To achieve any degree of standardization, it is necessary to break down the functions into a limited number of classifications. Basic functions that describe most of the major electronic elements of a system include the following:

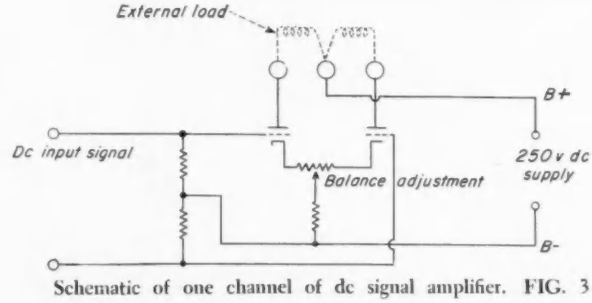
a) amplification of ac signals
b) amplification of dc signals
c) phase detection
d) power amplification for servo motor control
e) gain compensation
f) frequency sensitive circuits such as filters and servo stabilizing circuits
g) power supplies

Although standard frequency sensitive circuits and power supplies are available to some extent, this material will be limited to packaged components for functions a through e. Figure 1 shows a typical line of these components.

THE FIVE PACKAGED COMPONENTS



Schematic diagram of ac isolation amplifier. FIG. 2



Schematic of one channel of dc signal amplifier. FIG. 3

1. Ac Isolation Amplifier

An ac isolation amplifier is designed to accept an ac signal from a source that can tolerate only a minute amount of loading (because of its high impedance or its susceptibility to error if loaded). The unit presents a high impedance to its input signal and can supply a relatively low impedance load.

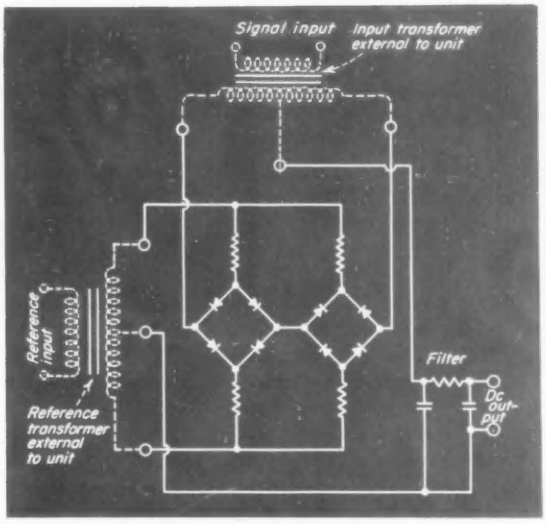
Negative feedback is used to maintain a constant voltage gain so that the output always bears a fixed amplitude relationship to the input signal. Negative feedback also reduces the phase shift between the input and output voltages.

The circuit diagram for a typical isolation amplifier is shown in Figure 2. It uses two double-triode tubes. The first tube acts as a voltage amplifier and phase inverter. The output of this stage is capacitively coupled to the push-pull output stage. The output transformer has a number of taps for flexibility in load matching and feedback circuitry.

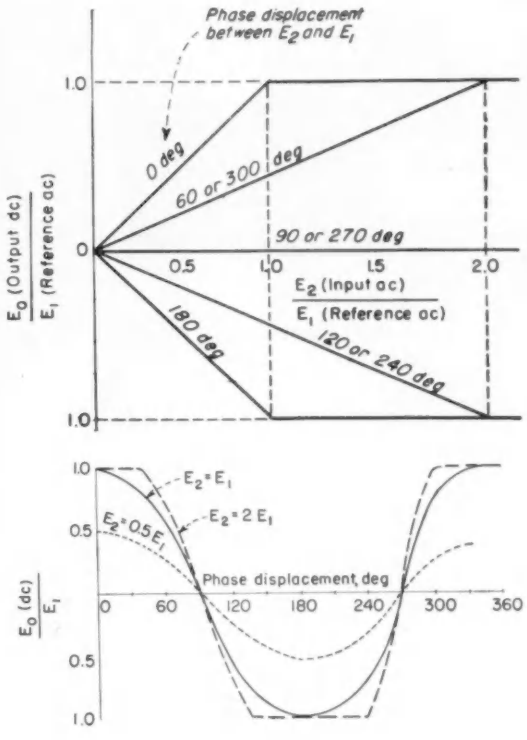
Typical uses for an isolation amplifier include supplying excitation voltages to resistance potentiometers or induction resolvers, and isolating the loading effects from high impedance circuitry.

2. Direct Current Signal Amplifier

Figure 3 shows one channel of a typical amplifier. A complete amplifier consists of two identical single-



Schematic wiring diagram of phase detector. FIG. 4



Performance characteristics of phase detector. In (A) the input amplitude and phase both vary, while in (B) the input amplitude is fixed and the phase relationship is variable. FIG. 5

stage balanced amplifiers. The two channels are intended to function separately and give outputs suitable for the control of a magnetic amplifier power stage, a sensitive relay, or an indicating meter. But they can also connect as a two-stage amplifier.

3. Phase Detector

A phase detector, Figure 4, produces a dc output signal that is a function of the amplitude of an input signal and its phase relationship with a fixed reference input of the same frequency.

If one input is energized with a fixed input signal, E_1, the output voltage throughout the linear range of operation will be

$$E_o = KE_2 \cos \theta$$

where K = constant of proportionality
E_o = dc output voltage
E_2 = magnitude of variable ac input signal
θ = phase angle between E_2 and the reference input, E_1

Figure 5 (A and B) shows the characteristics of the phase detector output as a function of the amplitude and phase of the input signal.

The phase detector can be used as a demodulator to produce a dc output indicating the phase and amplitude of the input signal. It can also be used as a null indicator to determine when two inputs are in a quadrature relationship. Figure 5 (B) shows that the variation of the output with phase change is most pronounced in the vicinity of the null points (90 and 270 deg). Thus the phase detector produces an output signal proportional to the amount the two input signals deviate from a quadrature relationship.

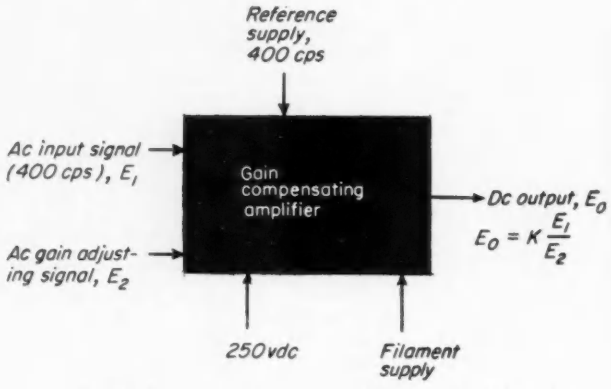
4. Gain Compensator

In many control systems there are wide variations in the gain of one or more servo loops over the normal operating range. Because of this it may be necessary to sacrifice accuracy at the low gain conditions and/or loss of system stability at the high gain condition unless compensation is provided.

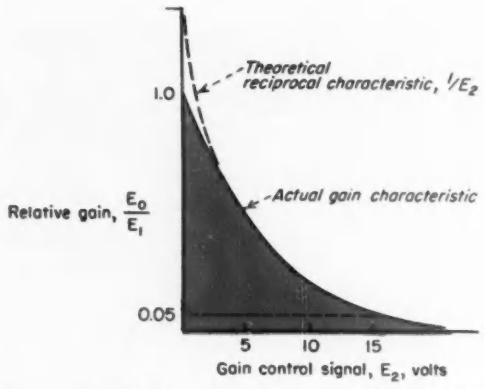
The gain compensation amplifier shown in Figure 6 offers a way to vary the amplifier gain as a function of an electrical control signal. A typical unit can be used with input signals from 400 to 2,000 cps.

Figure 7 shows the gain characteristic as a function of the dc control signal. The gain is approximately proportional to the reciprocal of the input signal. This characteristic is suited to many applications, as will be shown later. Gain change is obtained by adjusting the bias of a remote cutoff pentode. The usable range of gain adjustment is about 20 to 1.

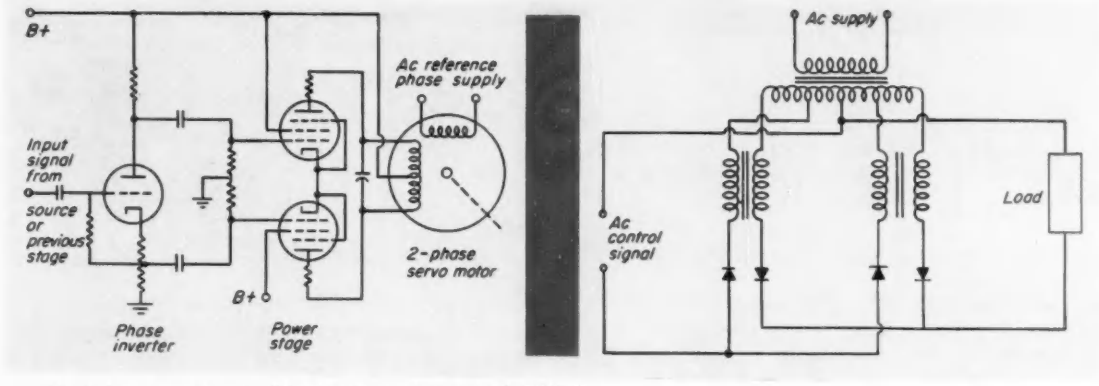
This gain compensating amplifier also includes a phase sensitive detector. This is convenient when it is used with a dc controlled magnetic power amplifier and also facilitates the incorporation of stabilizing networks. Thus the output is a dc signal whose polarity reverses with a reversal of phase of the ac input signal.



Block diagram of gain compensating amplifier. FIG. 6



Gain characteristics of gain compensating amplifier. FIG. 7



Typical vacuum tube amplifier for servo motor control. FIG. 8

Schematic of phase-reversing magnetic amplifier (fast-response half-wave). FIG. 9

5. Power Amplifiers

The power amplifiers that drive small servo motors in electromechanical systems are usually of the vacuum tube or magnetic amplifier type. Vacuum tube amplifiers such as shown in Figure 8 have long been the standard means for controlling low power servo motors in instrument applications. Many manufacturers of small induction type motors market standard amplifiers with high impedance, center-tapped control windings for plate-to-plate operation in conventional vacuum tube circuits. Thus no output transformer is required.

Recently, packaged magnetic power amplifiers have become available and their use has grown markedly as system designers learn about their characteristics.

The saturable transformer is a low gain magnetic amplifier, a variation of the saturable reactor. Its ac output voltage is proportional to the difference between two dc control signals. The output phase reverses depending on the relative magnitude of the control winding currents. Power gains of about 30 are typical for 400 cps units. Because of the low gain, saturable transformers usually need a preamplifier of the transistor, vacuum tube or magnetic type.

Magnetic amplifiers with positive feedback have much higher power gains and higher ratios of power gain to time lag than nonfeedback types. A phase reversible magnetic amplifier with external feedback is a typical example.

Another magnetic power amplifier is the fast response, flux reset type, Figure 9. This employs half-wave, self-saturating elements arranged so that the output delivered to the load during the gating half cycle is determined by the level to which the magnetic flux in the core has been driven during the preceding reset half cycle. Power gains of 100 to 1,000 per stage are typical.

HOW THESE COMPONENTS ARE USED

Induction Resolver Booster

The induction resolver is a variable mutual inductance with the coupling between the primary and secondary windings an accurate function of the angular position of the rotor. The primary windings usually are located on the stator and the secondary or output windings on the rotor. The two primary and two secondary windings are wound in space quadrature.

Typical resolver primary windings have impedance values of 2,000 to 5,000 ohms for 60 cps units and 5,000 to 50,000 ohms for 400 cps units. To prevent undesirable loading effects when the resolver is excited with signals from high impedance sources, a buffer amplifier must be used between the signal source and the resolver winding. The ac isolation amplifier can perform this function.

Figure 10 is a block diagram of a resolver-booster system. One amplifier channel is required for each primary winding. Unused primary winding should be shorted out.

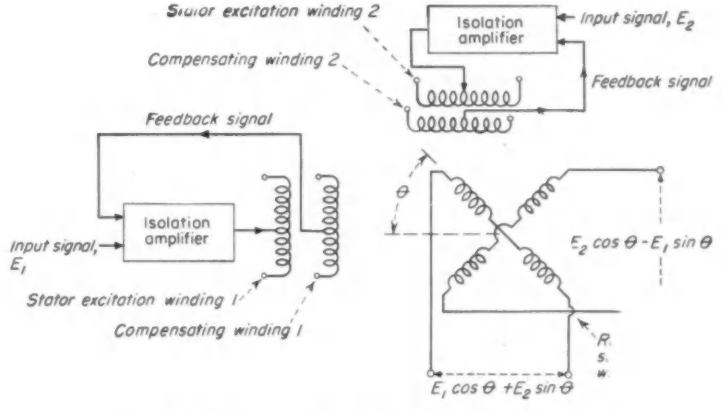
Figure 11 shows an isolation amplifier exciting a resolver equipped with compensating windings. These are auxiliary windings similar to the primary and wound in the same slots. By feeding back the voltage induced in the compensating windings, the primary winding is effectively made resistanceless and the secondary voltage at maximum coupling is proportional to the input signal and substantially independent of changes in temperature and line frequency.

Resistance Potentiometer Excitation

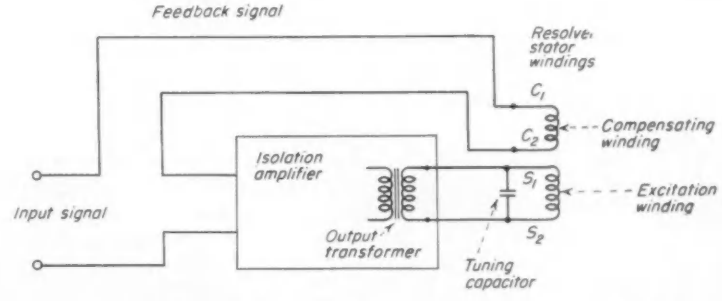
The isolation amplifier can supply ac excitation voltage to a resistance potentiometer just as it does to the induction resolver. Figure 12 shows an isolation amplifier exciting a potentiometer. The negative feedback signal is obtained from a separate feedback winding on the output transformer.

Electromechanical Phase Measurement

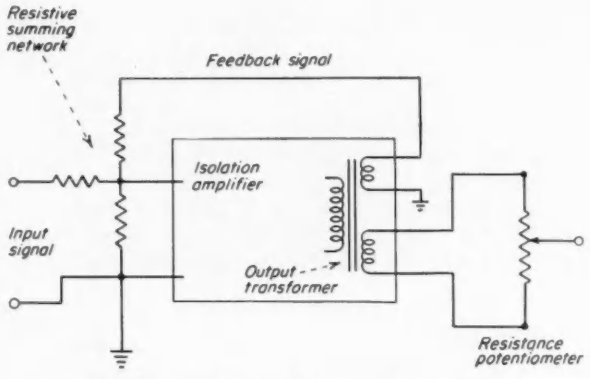
Figure 13 shows how an isolation amplifier and a phase detector can be combined with an induction resolver and a null indicating meter to result in an electromechanical phase measuring device.



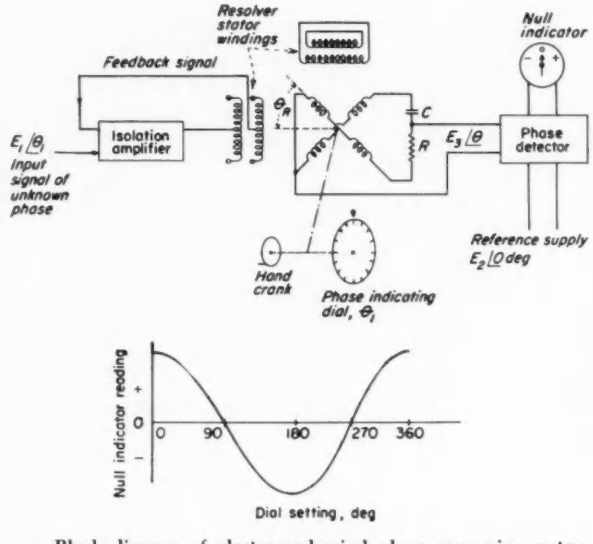
Isolation amplifiers used as resolver booster amplifie



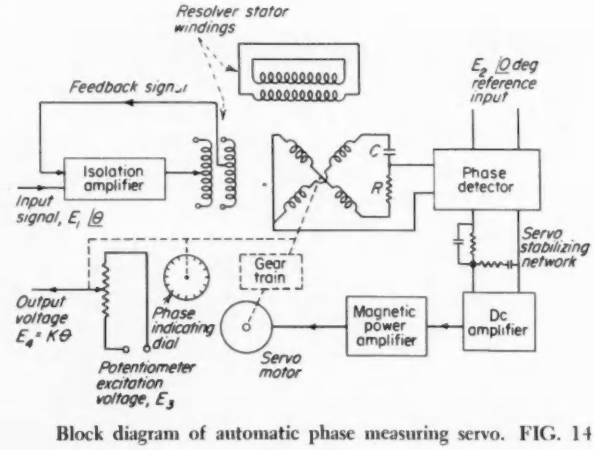
Isolation amplifier feeding winding compensated resolver. FIG. 11



Ac isolation amplifier feeding resistance potentiometer. FIG. 12



Block diagram of electromechanical phase measuring system and plot of null indicator reading versus dial setting for 0 equals 90 deg. FIG. 13



Block diagram of automatic phase measuring servo. FIG. 14

The resolver and the R_1 C_1 network act as a phase shift device that produces an output voltage E_3 equal in magnitude to $0.707E_1$ and at phase angle

$$(\theta_1 - 45 \text{ deg} - \theta_R)$$

Thus, rotating the resolver rotor shifts the phase of voltage E_3 with respect to E_1.

The characteristic of the phase detector is such that its output voltage is zero when the voltages E_2 and E_3 are in quadrature. Thus, by determining the angular position of the resolver rotor at which a null is produced, the phase displacement between the two input voltages E_1 and E_2 can be measured.

The ambiguity of the null indication (null is produced at both 90 and 270 deg displacement) can be resolved by noting the polarity of the error signal in the vicinity of the null. The 90 deg displacement is indicated when an increase in the value of θ_R near the null produces a negative indication on the null meter.

Automatic Phase Measuring Servo

A phase measuring and indicating system, similar to that previously described but servo driven for automatic, continuous operation, is obtained by adding a servo motor, magnetic power amplifier and dc signal amplifier. This system is shown in Figure 14. It will continuously produce an output voltage proportional to the angular displacement between E_1 and E_2. Phase measuring servos of this type are used in complex control systems.

Multipliers and Function Generators

The electromechanical servo multiplier is a common system for obtaining the product of two variables. Where one or both of the variables is in the form of a shaft position, simple methods can be used. However, if ac potentiometer excitation voltages are derived from high impedance sources, isolation amplifiers may be needed.

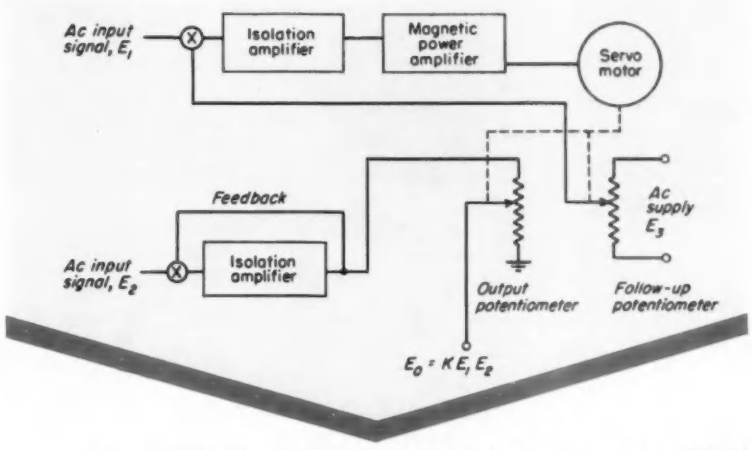
Where both signals are electrical, a servo system can be used to obtain a shaft position proportional to one of the input signals. Figure 15 shows such a system. The magnetic power amplifier is a fast response ac controlled type.

The same components will produce an output proportional to the sine or cosine of an electrical input when a nonlinear potentiometer is added, as shown in Figure 16.

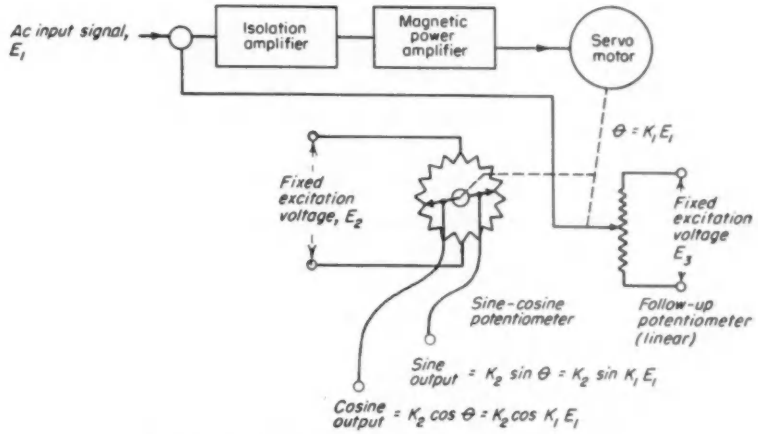
Function Generator With Gain Compensation

The servo multiplier and function generating system described above have constant servo loop gain at all input conditions. That is, the error signal produced per degree deviation from the null position is a constant regardless of input amplitude.

However, there are some operations better handled by systems in which the servo loop gain varies widely as a function of the input signal. If such systems must operate over a wide range of input conditions,



Servo multiplier with two electrical inputs and an electrical output. FIG. 15


Ac input signal, E_1
Isolation amplifier
Magnetic power amplifier
Servo motor
$\theta = K_1 E_1$
Fixed excitation voltage, E_2
Fixed excitation voltage E_3
Sine-cosine potentiometer
Follow-up potentiometer (linear)
Sine output $= K_2 \sin \theta = K_2 \sin K_1 E_1$
Cosine output $= K_2 \cos \theta = K_2 \cos K_1 E_1$

Sine-cosine function generator, servo driven. FIG. 16

system performance can be compromised. At low gain conditions accuracy is poor, while at the higher gain conditions system damping is reduced and excessive hunting or even continuous oscillation can result. Proper use of the gain compensating amplifier will extend the useful range of these systems.

Figure 17 shows an electromechanical servo system that will compute the square root of the input signal. At low values of the input signal, E_1, the error signal per degree rotation of the output shaft is low. At higher values this gain factor increases.

With a constant gain amplifier, system accuracy will rapidly deteriorate when E_1 decreases below 25 per cent of its maximum value. The plot of gain versus input signal with and without the gain compensating amplifier graphically shows the improved performance that is possible through compensation.

Electromechanical Triangle Solver

A common computing problem is the solution of a right triangle for the hypotenuse and angles when the length of the two legs are known. This problem —the conversion of rectangular to polar coordinates —can exist in a gunfire control application, where the horizontal distance to a target and its elevation are known and it is required to compute the slant range and angle of elevation, Figure 18.

A block diagram of a system that will continuously solve this problem is shown in Figure 19. The stator windings of the resolver are excited with the voltages E_1 and E_2, which are proportional to the two legs of the triangle to be solved. The outputs of the resolver rotor windings are

$$a— \quad E_1 \cos\theta + E_2 \sin\theta$$
$$b— \quad -E_1 \sin\theta + E_2 \cos\theta$$

If output b, which appears across resolver terminals R_3R_4, is fed to the input of the servo amplifier, the system will be driven to a null when this output is equal to zero.

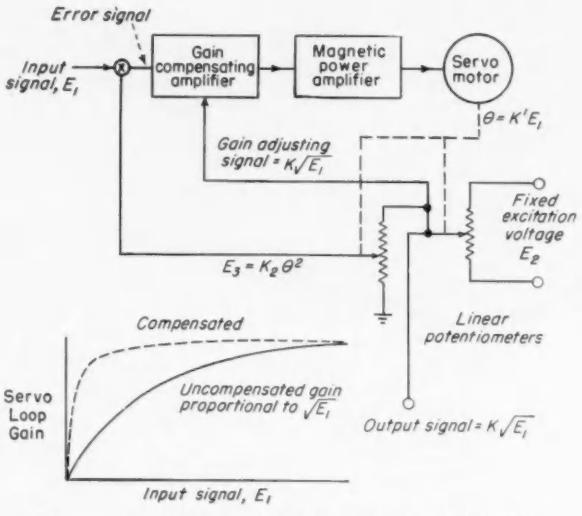
$$E_2 \cos\theta - E_1 \sin\theta = 0$$

$$\frac{E_2}{E_1} = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

Therefore, the angle θ at which the resolver nulls is equal to

$$\tan^{-1} \frac{E_2}{E_1}$$

This angle can be measured electrically by a potentio-



Square root calculator with gain compensator. FIG. 17

meter geared to the shaft of the resolver.

Output a, which appears at resolver terminals R_1R_2, can be expressed as follows for any angle θ:

$$E_1 \cos\theta + E_2 \sin\theta$$

At the servo null position

$$E_1 \frac{E_1}{\sqrt{E_1^2 + E_2^2}} + E_2 \frac{E_2}{\sqrt{E_1^2 + E_2^2}} = \sqrt{E_1^2 + E_2^2}$$

Thus, the voltage at resolver terminals R_1R_2 is proportional to the square root of the sum of the squares of the two input signals and is, therefore, proportional to the hypotenuse of the right triangle with legs E_1 and E_2.

If the servo amplifier gain is constant, the loop gain is proportional to the rate of change of the error voltage appearing at the amplifier input as the resolver rotor angle θ varies around the null point. Thus

$$\text{gain} \cong \frac{Kd(\text{output } R_3R_4)}{d\theta}$$

$$\text{gain} \cong E_2 \sin\theta + E_1 \cos\theta$$

Since only the gain in the vicinity of the null point is of interest and the angle θ at null equals $\tan^{-1}(E_2/E_1)$, the servo gain is proportional to

$$\sqrt{E_1^2 + E_2^2}$$

Thus the servo gain is a function of the amplitude of the two input signals.

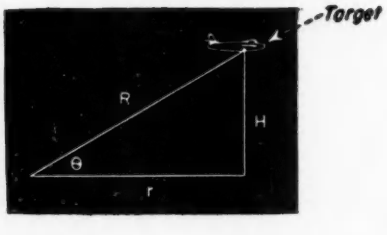
For the ideal conditions of constant servo loop gain, the amplifier gain should be proportional to the reciprocal of the uncompensated gain.

$$\text{ideal amplifier gain} = \frac{K}{\sqrt{E_1^2 + E_2^2}}$$

By injecting a dc voltage proportional to

$$\sqrt{E_1^2 + E_2^2}$$

into the gain control input of the gain compensating amplifier, this characteristic is approximated and the range of inputs for accurate system performance is extended. Figure 19 includes a plot of servo gain versus the gain factor with and without gain compensation.



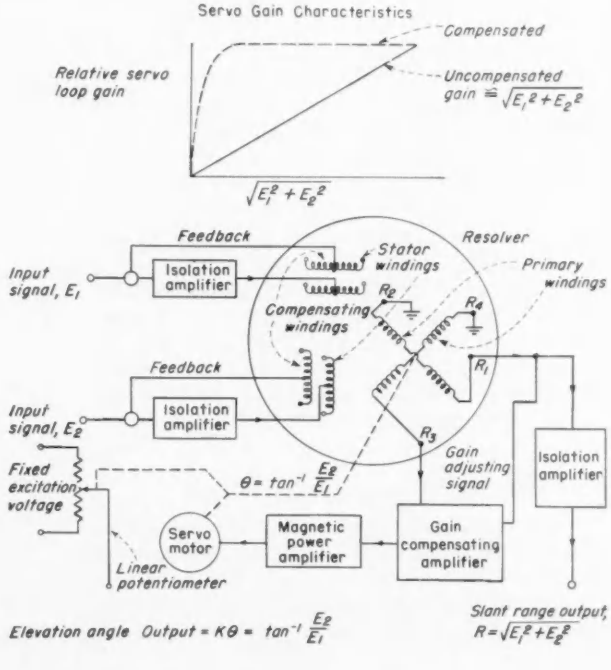
H = *Target elevation*

r = *Horizontal range to target*

R = *Slant range to target*

θ = *Elevation angle of target*

Triangular range problem to be solved. FIG. 18



Block diagram of triangle solving computer plus plot of servo gain characteristics. FIG. 19

The "Kitty Hawk" of Automation

The very first automatic feature in motor control was the no-voltage release in the Cutler-Hammer Bulletin 10 Starter of 1892. The starter handle was held in the "on" position by an electromagnet and returned automatically to the "off" position whenever the power supply failed. This protected men at machines from sudden unexpected restarting, motors against burn-out due to the inrush of uncontrolled current.

Tomorrow dawned 63 years ago!

New ideas are seldom as new as most people think. Automation is typical. If automation is tomorrow's way of manufacturing, this *tomorrow* dawned 63 years ago with the beginning of automatic electrical control. What is now possible in automation is not the result of sudden discovery but the application of control techniques and equipment developed through *decades* of experience.

This is an important consideration to anyone interested in automation planning. Automation is always a major project. It requires a large investment in planning and engineering . . . and an outlay for equipment often without precedence in a company's experience. The rewards for success can be momentous. But the penalties for mistakes can be disastrous.

Able management has been quick to realize the safeguards provided by maximum automatic control experience in even the earliest exploratory discussions of automation. As a consequence, Cutler-Hammer engineers and Cutler-Hammer Automatic Control have already helped in turning "visionary" plans into astounding automation realities in such diverse industries as cement, glass, paper, rubber, sugar, steel, textiles and automotive.

If automation is a "must" in your future, now is the time to act to make it a competitive advantage rather than a handicap. It cannot be rushed into being; it always requires a vast amount of skillful planning and ingenious engineering. Invite Cutler-Hammer engineers to participate. Their experience is almost sure to speed your project. It can help you avoid false starts, prevent impractical or needlessly complicated constructions. It may even point the way to unsuspected automation possibilities, as it has for others. Write, or wire CUTLER-HAMMER, Inc., 1467 St. Paul Avenue, Milwaukee 1, Wisconsin.

CUTLER·HAMMER

MOTOR CONTROL

C·H

Better Synchro Repeaters from Damper-Stabilized Feedback

A servo drives an indicator dial to null a synchro control transformer. Viscous-coupled inertia damping gives exceptionally fast and accurate response.

JOHN E. WARD, M.I.T. Servomechanisms Laboratory

Checking the accuracy of modern automatic airborne fire-control systems has posed a number of difficult instrumentation problems. A very prominent one involves physical angles in the system under test. These must be measured and recorded very accurately.

Suppose it is necesary to sample a certain number of times per second, with an accuracy of plus or minus 0.5 milliradian over an angular range of 120 deg, the position of a moving radar antenna or gun turret. Frequencies as high as 8 cps are usually present in the motion of such antennas and turrets. Thus, an over-all dynamic accuracy of plus or minus 0.03 deg and a resolution of about one part in 4,000 are needed in a process that includes measuring, recording in the aircraft, and later reading on the ground for data analysis.

Recording is the most critical part of this process. There are possibilities of error in transferring measurements to the storage medium, in the medium itself, and in reading the medium.

Available analog recorders, such as direct-writing or photographic oscillographs, are out of the question where such accuracy and resolution are demanded. One form of digital recording is to display information numerically on a dial, where it can be photographed and later recovered without loss of accuracy. Fire-control instrumentation usually is based on this kind of system.

Still, the indicating dials must be driven so that they repeat accurately the measured position. Synchro links are unsatisfactory in many applications because of poor dynamic accuracy and frequency response and lack of sensitivity to errors caused by vibration, temperature, and friction.

THE DATA REPEATER

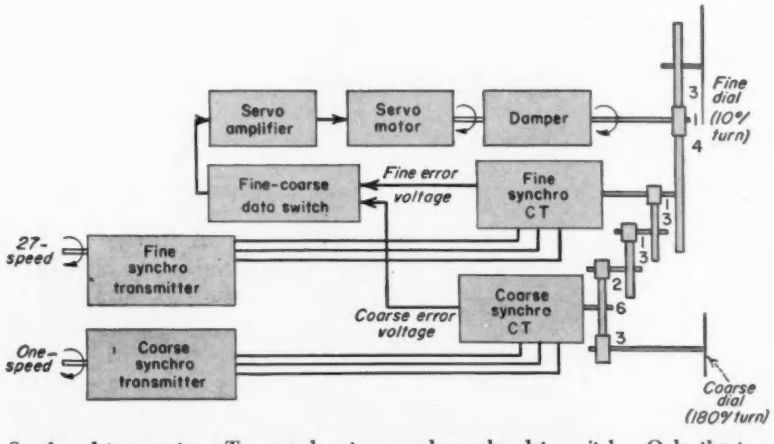
The data repeater developed at M.I.T. is packaged in a 3-in. diam aircraft instrument case, takes 9 in. behind the panel, and weighs 3½ lb. Its fine dial indicates 10 deg per revolution by $\frac{1}{10}$-deg increments. Its coarse dial indicates 120 deg in 10-deg increments. A vernier divides the fine dial to 0.01 deg.

Figure 1 is a diagram of the synchro data repeater. Although it incorporates a two-speed data system,[1] only two gear meshes in the repeater are important when it is in normal operation on fine data: that between the motor and the fine synchro, and that between the motor and the fine dial. Gear errors and backlash that occur at only two points can be contained.

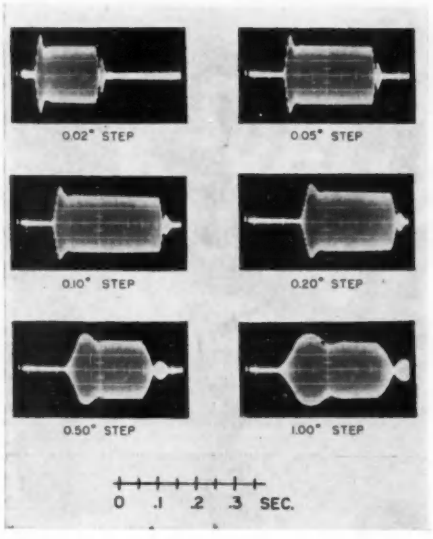
Due to viscous-coupled inertia damper stabilization,[2] no electrical compensation is needed and the servo amplifier is a straight-forward ac type with a gain of about 400. Thus, the repeater is drift-free and insensitive to changes in carrier frequency.

The damper designed for the repeater has a turned magnesium shell (density 1.74) 0.030 in. thick with an inertia of 10.1 gm-cm². The viscous-coupled slug is 2.5 cm diam by 2 cm long. It is sintered tungsten (density 16.7) and has an inertia of 120 gm-cm². Thus the inertia ratio for the damper alone is 12 to 1.

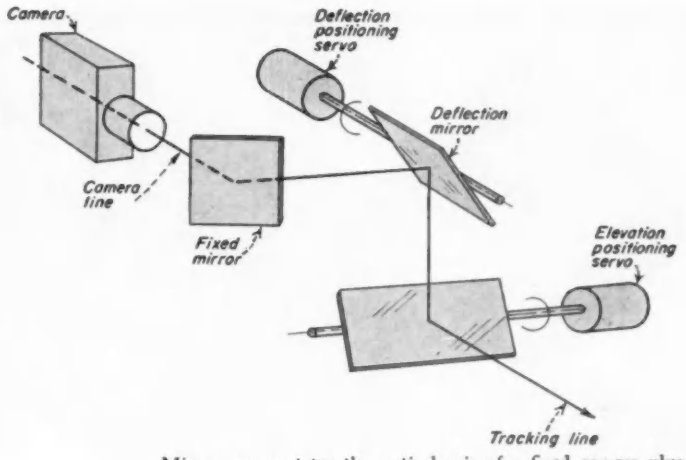
The radial clearance between the slug and the shell is 0.020 in., and a fluid viscosity of 3,000 centipoise gives break frequencies of 14.7 and 109 cps. Since these frequencies vary linearly with viscosity, servo band-width can be varied with silicone fluids of dif-



Synchro data repeater. Two-speed system employs relay data switch. Only the two gear meshes at the damper pinion are important for fine data. There is no electrical compensation in this 400 cps system with Mk. 8 servo motor. FIG. 1



Repeater transient response. Repeater is linear for step inputs up to about 0.1 degree. FIG. 2



Mirror servo rotates the optical axis of a fixed camera plus or minus 20 deg in both elevation and deflection. FIG. 3

ferent viscosity in the same damper.

PERFORMANCE

Two considerations in the performance of the data repeater are static accuracy and following ability. The former is associated mainly with the accuracy of the data transmission and the dial; the latter is primarily a matter of servo performance.

Synchros with an error spread of 20 min give a maximum static error of 0.02 deg between the 27-speed synchro transmitter and the dial indication. But any gearing error between the 27-speed transmitter and the position being measured must be considered when examining over-all error in a given installation. No additional error is introduced by photographing and projecting the dial image, even though the image may be reduced by a factor of 20 to 1 on 35-mm film.

For the repeater to indicate faithfully at frequencies up to 5 cps, a gain-crossover frequency of 40 cps and a maximum amplitude ratio of 1.3 were specified. The loop stiffness is 35 motor volts per degree at the motor shaft. The velocity and acceleration constants are approximately 13,000 sec^{-1} and 23,000 sec^{-2}. These high figures result from damper stabilization and make dynamic error negligible.

Figure 2 illustrates transient response. For small steps within the linear range of about 0.1 deg, the repeater has a settling time of about 0.04 sec. For a 1-deg step the settling time increases to approximately 0.2 sec. Although transient measurements such as these are the best way to set the gain in a damper servo, step inputs are not expected in practice when the repeater is following a physical system.

For much larger steps, as in initial synchronization, the settling time becomes as much as 5 sec. In most cases, however, this relatively long synchronization time is not a serious disadvantage, because the repeater can be synchronized prior to data taking.

Maximum acceleration is about 900 deg per sec per sec, twice that of the servo-driven systems the repeater has to follow. Maximum slew speed is 320 deg per sec. One outstanding feature of a damper-stabilized servo is extreme smoothness of operation. The repeater follows smoothly at speeds as slow as 0.01 deg per sec, giving a total speed range that is greater than 30,000 to 1!

FURTHER APPLICATIONS

In the Helipot Data Repeater, the feedback element is a 10-turn helical potentiometer. This repeater, packaged in the same type housing as the synchro data repeater, indicates range in radar sets, and the angular position where potentiometer rather than synchro data are available. The damper assembly is the same but the fluid viscosity is lowered to 500 centipoise to give a gain crossover frequency of 12.5 cps. Loop stiffness is 2.3 v (0.052 in.-oz) per degree at the motor shaft. The motor-to-Helipot gear ratio is 7 to 1, and the gear train includes a slip clutch and a washer-pile limit stop to protect the potentiometer.

The Helipot Data Repeater has been used with both ac and dc excitation on the feedback potentiometer, but is subject to drift and calibration errors in either case. With a 0.05 per cent potentiometer it is linear to 0.1 per cent between input voltage and dial indication, and the fine dial, mounted on the potentiometer shaft, reads directly to one part in 1,000.

The servo developed for the data repeaters is also used in a unit called the mirror servo, Figure 3. It is often better to rotate the optical axis of a fixed camera, instead of mounting the camera on a rotating member. This is particularly so when tracking-error movies are needed for airborne radars that have small antennas, opaque radomes, and severe space limitations within the radome.

Two damper-stabilized servos rotate the azimuth and elevation mirrors to displace the camera optical axis plus or minus 20 deg in both elevation and deflection within 1 mil, or 0.06 deg. These servos have the same performance as the synchro data repeaters.

RELIABILITY

For about four years now the repeaters described here have been evaluating bomber tail defense, tracking, and bombing systems. More than sixty repeaters are in operation and reliability has been excellent. In a typical application, ten data repeaters installed in a photo theater indicate positions of a radar and turret, prediction angle components, radar range, and roll, pitch, and yaw motions of an aircraft. They are photographed eight times per second.

REFERENCES

1. *HOW TO DESIGN SPEED SWITCHING CIRCUITS*, Basil T. Barber, CONTROL ENGINEERING, Nov. 1954, pp. 50-53; Dec. 1954, pp. 33-36.
2. *DAMPER STABILIZED INSTRUMENT SERVOMECHANISMS*, Albert C. Hall, AIEE Technical Paper 49-79, Dec. 1948.

New TRANSISTORIZED MINIATURIZED

TYPE 2007T

400 CYCLES ±.02%

28 VOLTS D.C.

SPECIFICATIONS

INPUT
20 to 35V DC
at approx. 5 m.a.

OUTPUT FREQUENCY
400 or 500 cycles

Type 2007T
+ −.02% from −65° to + 85°C.

Type R2007T
+ −.002% from + 15° to + 85°C.

Type W2007T
+ −.005% from −65° to + 85°C.

OUTPUT VOLTAGE
5 volts, sine wave.

Substantially uniform
from −65° to + 85°C.

LIFE EXPECTANCY
several times that of vacuum tubes

INTERNALLY SHOCK MOUNTED
on Silastic

MAGNETICALLY SHIELDED

HERMETICALLY SEALED

OCTAL BASE

SIZE
4½" x 1½" diameter

WEIGHT
7 ounces

COMPLETE INFORMATION ON REQUEST
PLEASE SPECIFY TYPE 2007T

Precision

FREQUENCY STANDARDS

These units, which are the result of several years of development and testing, offer a new standard of simplicity and reliability. Particularly noteworthy is the uniformity of output signal voltage with temperature change. Small size and light weight make them ideal for airborne and portable use.

For applications where only higher B voltages are available, a simple voltage reducing circuit may be used.

American Time Products, Inc.

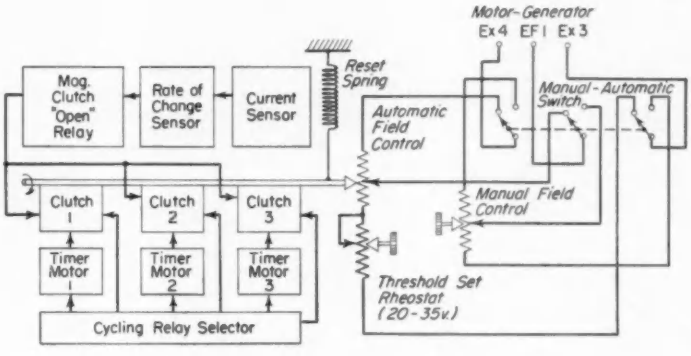
580 Fifth Avenue ***New York 36, N. Y.***

MANUFACTURING UNDER PATENTS OF WESTERN ELECTRIC COMPANY

Dielectric Plating Goes Automatic

Programmer controls current to minimize error and tedium in a dielectric plating process.

GEOFFREY POST, General Cybernetics Corp.



Automatic controllers now program the dielectric plating process at the Sanford Processing Co., Los Angeles. Individual controllers for each plating vat are mounted on a central panel, allowing one operator to supervise five batches simultaneously.

The plating techniques include setting the threshold (initial) voltage, maintaining the current-time relationship during the plating period, and detecting "burning" (current surges). As the dielectric is plated on the components, the circuit resistance increases; adjustment of the field rheostat raises the generator voltage to maintain constant current.

When this operation is manually controlled the operator adjusts the rheostat to the threshold voltage and slowly increases the plating voltage. Should a current surge, as seen on a meter, occur during any portion of the plating cycle, the operator quickly drops to threshold voltage and starts replating. If current surges do not develop, the current is raised for a second and shorter period and finally for a very brief period.

The automatic control circuits lessen this tedious side of the plating problem. Manual control, however, is retained for new plating programs and maintenance.

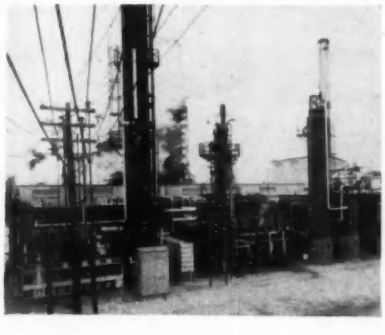
The block diagram shows both *manual* and *automatic* control circuits, including the simple changeover switch. On *manual* the operator controls the plating process. On *automatic* the controller is self-operating, except for start-up. The *threshold set rheostat* is manually adjusted between 20 and 35 v and the power is switched on. A meter checks the threshold voltage.

A timer motor rotates the automatic field control shaft through a magnetic clutch, increasing the voltage at an initial rate of 1 v per 3 min. The rotation also winds up the reset spring connected to the shaft. At the end of the first period, adjustable from 10 to 20 min, the cycling relay starts the next rate of 2 v per 3 min. This period, also adjustable from 10 to 20 minutes, leads to the third period of 3 v per 3 min and continues to maximum voltage.

Current surges, exceeding five per cent of nominal, trigger the magnetic clutch. With the motor no longer connected, the reset spring forces the rheostat back to the threshold voltage.

The controller, designed by General Cybernetics Corp., is reliable and needs little maintenance. Mechanical and magnetic components vary the low-power generator field controlling 200 to 2,000 amp for plating.

• • •



Electronic Controls Qualify On Altreco Port Arthur Catformer

After a year's operation, Atlantic Refining reports on the Swartwout electronic control for its 8,000 bbl catformer:

- ▶A 50 per cent saving in initial cost
- ▶A 50 per cent gain in response speed
- ▶Excellent accuracy; good maintenance

But it also lists needed improvements:

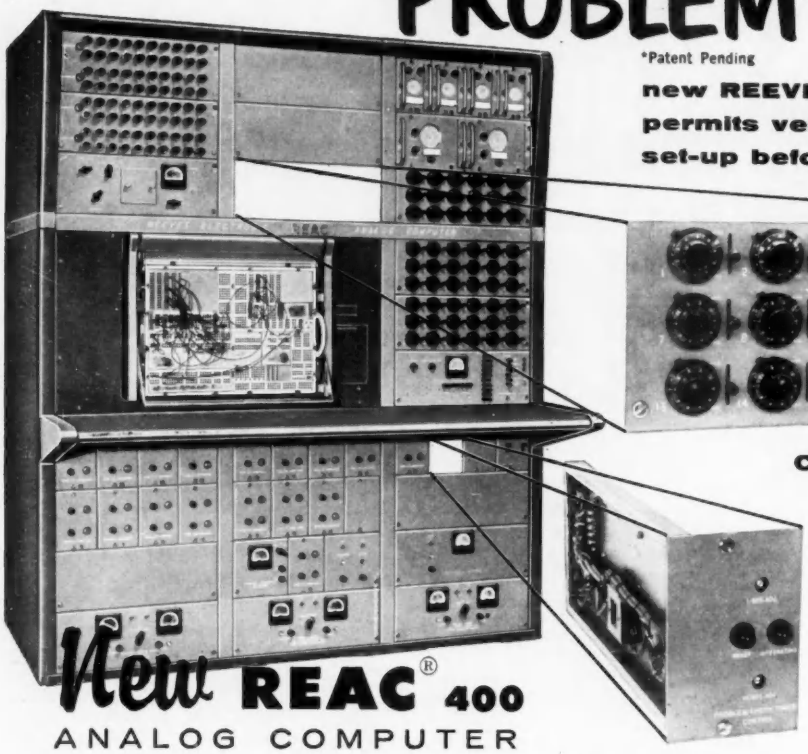
- ▶A less elaborate power supply
- ▶An indicator by each valve
- ▶Faster valves to fit system response

Relays (right) now actuate pneumatic valves at the process. Electric or hydraulic valve operators may replace these soon. Note also the lack of graphic design in the control console.

PROBLEM CHECK*

*Patent Pending

new REEVES development permits verification of problem set-up before a problem is run



New REAC® 400
ANALOG COMPUTER

CHECKS:

- ★ Diagramming of the problem from the equation.
- ★ Patching of the problem from the diagram.
- ★ Operation of all computer components to be used.

It's the only economical way . . .

Prepatch boards are, of course, prepared away from the machine. "Problem Check" means that only an absolute minimum of time is required on the machine to check the problem set-up in its entirety. A great deal of expensive checking and cross-checking while the problem is on the machine is thereby eliminated.

"Problem Check" is a new method developed by Reeves to verify analog computer circuits **without disturbing the problem set-up.** Checking is done directly from the equation **before** the problem is run, and the operation of every computing element is checked. Further, if the output of any computing element is not correct, the location of the difficulty is indicated, and the trouble can be quickly and easily found. After "Problem Check," runs may be taken on the machine with assurance that the set-up is correct and that the machine is functioning properly.

REVIEW THESE OUTSTANDING REAC® 400 FEATURES

New HIGH SPEED SERVOS
Servo multipliers have bandwidth over 50 cps. Velocity 1500 v/sec. Six gang pots; two tapped with front panel plug-in turrets for function generation.

New HIGH SPEED RESOLVERS
Vastly improved dynamic performance . . . 35-cycle bandwidth. Rectangular and Polar operation; Full AGC either mode requires no trimming. Front panel plug-in turrets for function generation.

New BUILDING-BLOCK CONSTRUCTION
Permits assembly of computer elements in any desired combination to do particular job or expand existing installation. Completely adaptable to your specific requirements.

New CONVENIENT PATCHBAY
Available in units of 1632, 3264 or 4896 holes for maximum flexibility. Color-coded mask aids in patching. Patchboard changes possible during operation.

New POWERFUL AMPLIFIERS
New dual amplifier chassis, individually chopper-stabilized. Noise less than 3 mv rms in cabinet. Phase shift 0.075° @ 100 cps. Bandwidth over 10 KC in cabinet.

Reeves INSTRUMENT CORPORATION

REEVES INSTRUMENT CORPORATION
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209 East 91st St., New York 28, N. Y.

REAC Analog Computers

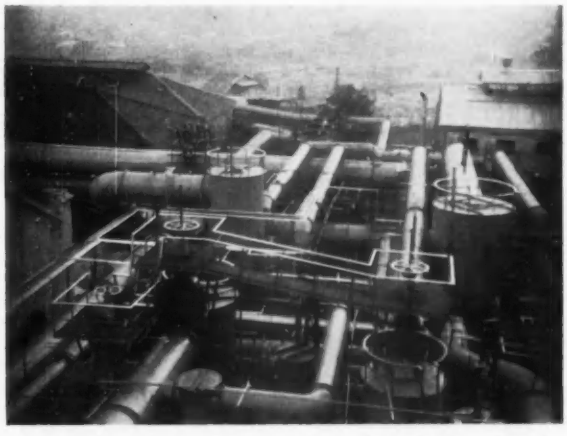
Precision Floated GYROS

Precision RESOLVERS and PHASE SHIFTERS

SERVO MECHANICAL PARTS

3RV55

Control room for dilution plant. Recorders on far wall indicate content of gas being made. FIG. 1



Some of the mixers and piping involved in the heating value control systems. FIG. 2

Dilution With Feedback Pays Off, 8:1

Tokyo Gas Co. has a wonderful argument for systems analysis. It cost $100,000 to make heating value control automatic. But it saved $800,000 worth of expansion.

SADAHIKO ARAKI, Tokyo Gas Co.

The Tokyo Gas Co. supplies 4 million cubic meters of gas each day to Japan's largest metropolitan area (pop. 7 million). The construction and engineering department applied automatic control to the gas diluting plant that controls heat content and reduced the 3 per cent variation in heating value, inevitable with manual control, to less than 0.7 per cent.

More remarkable, though, is the better use of gas holders made possible by automatic control. The heating value of the output gas is specified at 3,600 kilocalories per cubic meter. With automatic control the high calorie gas can be diluted just before delivery. This means that the existing 3,600 kcal gas holders can now be used to store 9,000 kcal gas. Thus, the storage is effectively increased by 9,000/3,600, or approximately 2½ times.

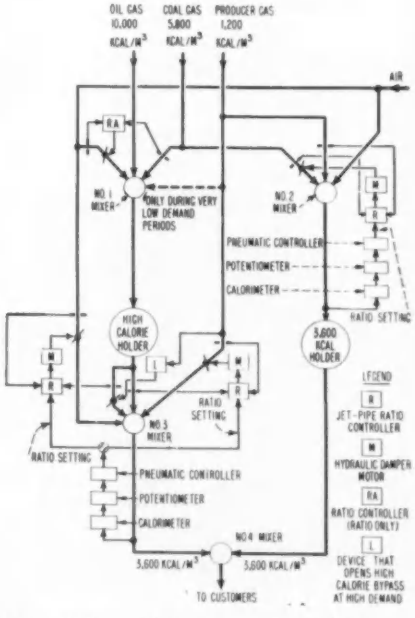
The company had been facing the necessity of buying new holders due to increasing demands for gas. Storing high calorie gas, however, was the same as getting 120,000 cubic meters of extra holding capacity. New holders of that capacity would have cost $800,000.. The heating valve control system cost only $100,000.

The system's measuring element is a Junkers Calorimeter. The temperature rise in the calorimeter is measured by a thermocouple, and recorded by an electronic potentiometer. The potentiometer controls a proportional plus reset plus rate pneumatic controller. This in turn controls the hydraulic ratio regulator that regulates the flow ratio of high calorie gas (oil gas plus coal gas) to produce gas and air. See Figure 3.

The Junkers is a water flow calorimeter; hence, it is sluggish. It has a time constant of two minutes and a dead time of three minutes. It is used because it is inexpensive and reliable.

The lag in the calorimeter is balanced by the small holder for 3,600 kcal gas. This, with the pipe sizing and arrangement, filters the shock of a demand change before it can affect the heat content of the gas.

(Mr. Araki plans to give complete details of his system at the Sixth International Gas Conference in New York, Sept. 26-30, 1955.)



Low-calorie producer gas and air dilute the high-calorie oil and coal gases. Left hand system is main supply; right side has storage to filter demand surges. At high demands, the high-calorie bypass opens and air is added; producer gas rate is constant. FIG. 3

IBM selects DU MONT TYPE 329* as test oscillograph for their new type 702 computer

When IBM Corporation, world's largest manufacturer of computer equipment, produced their new Model 702, an essential phase of the project involved selection of a cathode-ray oscillograph to go into the field with each computer as standard test equipment. Requirements were strict.

IBM's approach to the problem was to conduct side-by-side evaluation with other competitive instruments. On the basis of actual performance, they selected the Du Mont Type 329 as their test oscillograph.

What are some of the primary reasons why IBM decided on the Du Mont Type 329? Excellent sensitivity—either d.c. or a.c. coupled. Precisely calibrated sweeps with movable notch magnification—ideal for making accurate measurements. Brightness—adequate for display of very fast pulses. Synchronization simplicity—the Type 329 "locks in" on almost any type of signal. Stability—the trace remains steady as a rock despite power line fluctuations, etc. Reliability in service—calibration adjustment requires no extra test gear and is a simple one-step process. And virtually any tube may be replaced without special selection.

Another factor contributing to the selection of the Type 329 was the well known Du Mont Field Service Organization, which assures that regardless of where in the United States the equipment is used, swift, competent service facilities are in the immediate vicinity.

If you have instrumentation requirements, Du Mont facilities are always available for discussion and recommendations. Write us today for complete information on the Type 329, or on any problem you may have relating to cathode-ray instrumentation.

*"Modified slightly for IBM's application."

DU MONT

ALLEN B. DU MONT LABORATORIES, INC. • TECHNICAL SALES DEPARTMENT
760 Bloomfield Avenue, Clifton, New Jersey

Problem Checker Checks Computer Too

A simple, inexpensive circuit can eliminate analog computer patching errors and catch computer malfunctions at the same time.

R. D. McCOY and B. D. LOVEMAN,
Reeves Instrument Corp.

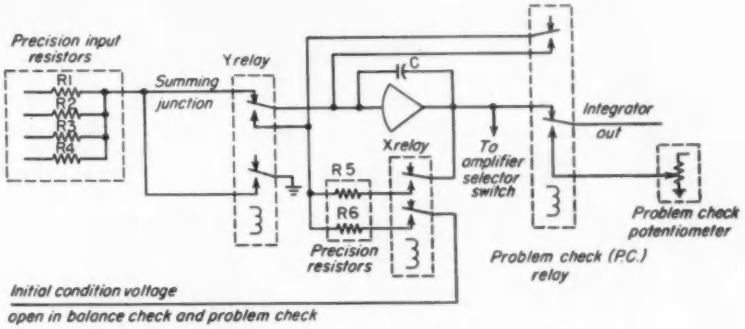


TABLE OF INTEGRATOR MODES

Relay	Problem check static	Problem check dynamic		Balance check	Reset	Operate	Hold
		Operate	Hold				
X	E	D	D	E	E	D	D
Y	D	D	E	E	E	D	E
P.C.	E	E	E	D	D	D	D

E-Energized, D-Deenergized

Circuitry required per integrator for Problem Check. Table shows relay positions for various checking modes. FIG. 1

The modern analog computer is a versatile, accurate, and reliable tool for dynamic systems engineering. But the operator can make mistakes, and occasional machine malfunction can cause trouble.

The increasing size and scope of computers and the complexity of problems handled make setup errors even more serious. Prepatching of problems on removable patch panels is invaluable as a time saver, but presents another opportunity for mistakes. Thus, it has become necessary to provide a system for adequately checking:

- ▶ Problem coding
- ▶ Patching
- ▶ Scale factor potentiometer settings
- ▶ Computer component operation

The "Problem Check"* system does all this, and is easy to use. Checking of computations is minimized and sources of trouble are localized. This is all done without disturbing the problem setup. Also, the system is inexpensive.

MODES OF OPERATION

Problem Check circuitry (Figure 1) involves each integrator in the computer and provides six basic operating modes: balance check, reset, operate, mold, problem check static, and problem check dynamic.

In **balance check,** the summing junction is grounded and resistor *R5* is paralleled with the integrating condenser, *C*. The dc amplifier can then be set to zero output by its balance potentiometer if necessary.

Reset connections are the same as in balance check except that the initial condition voltage is fed from the patchbay to the integrator grid through *R6* by a relay contact closed only during reset. Thus, integrator initial conditions are established.

In **operate,** the summing junction is connected to the grid and the integrator's output is the negative of the integral of the sum of its inputs, with appropriate scale factors, plus the initial condition. *R5* is not in parallel with *C*.

In **hold,** connections are the same as for balance check except that *R5* is not in parallel with *C*. With no input, the integrator output voltage remains at whatever value exists when the integrator is put into hold.

In **problem check static,** the integrator is in operate except that its output is disconnected from the "integrator out" terminal on the patchbay and *R5* parallels *C*. Its output is the negative of the sum of its inputs. A voltage from the "problem check potentiometer" replaces the integrator output at the patch bay terminal and becomes an input to the problem.

Connections of **problem check dynamic** are the same as in problem check static except that *R5* no longer parallels *C*. After integrating for a preset interval, the integrator is put automatically into hold. Note that the output remains disconnected from the patchbay with the problem check potentiometer substituted for it.

PROBLEM CHECK STATIC

To clarify the use of Problem Check, consider the system of differential equations mechanized in Figure 2:

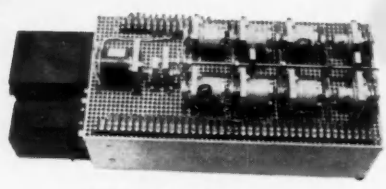
$$\frac{dv}{dt} = -32.2 \sin \theta - 8(10^{-5})\, v^2 \qquad (1)$$

$$v \frac{d\theta}{dt} = -32.2 \cos \theta \qquad (2)$$

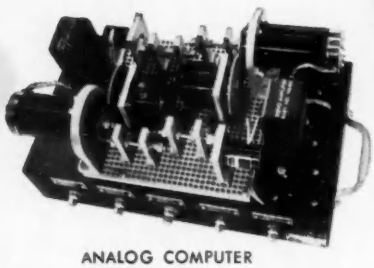
The problem check potentiometers

A SAMPLE PROBLEM SHOWS HOW TO USE THE CHECK ➧

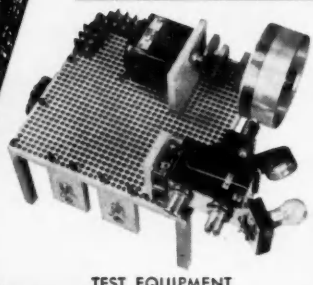
*Pat. Pending



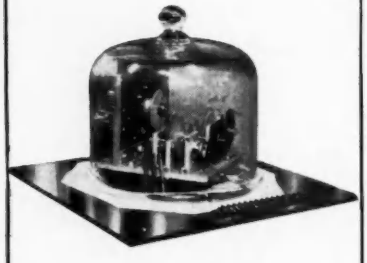
REMOTE CONTROL



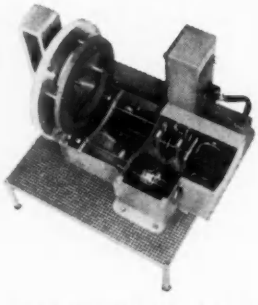
ANALOG COMPUTER



TEST EQUIPMENT



INSTRUMENT BREADBOARD



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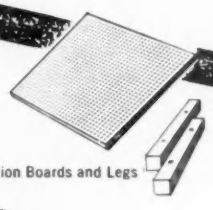
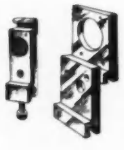
SOLVE

Electro-mechanical problems... IN THE LAB! with Servomechanisms' efficient, economical Mechanical Development Apparatus

Pictured above are typical Mechanical Development Apparatus (MDA) assemblies, complete with electrical components. MDA is an assortment of standardized, precision-built, mechanical components designed for the purpose of simulating instrument and control systems in the breadboard phase of development. The apparatus makes designing extremely fast and economical. An appropriate group of these versatile units can be quickly assembled into a desired mechanism. The components lend themselves to endless use and re-use due to the flexibility of its design. Only a small assortment is needed to cover a multitude of problems. Prove out your design, quickly and economically with these versatile "tools"

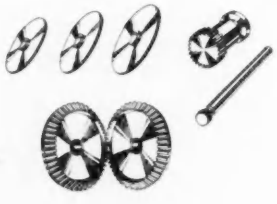


Foundation Boards and Legs

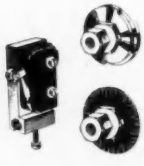


Mounting and Bearing Blocks

Stainless Steel Shafts and Gears



Lead Screws, Clutch



Dials, Cams, Switch

Limit Stop, Couplings

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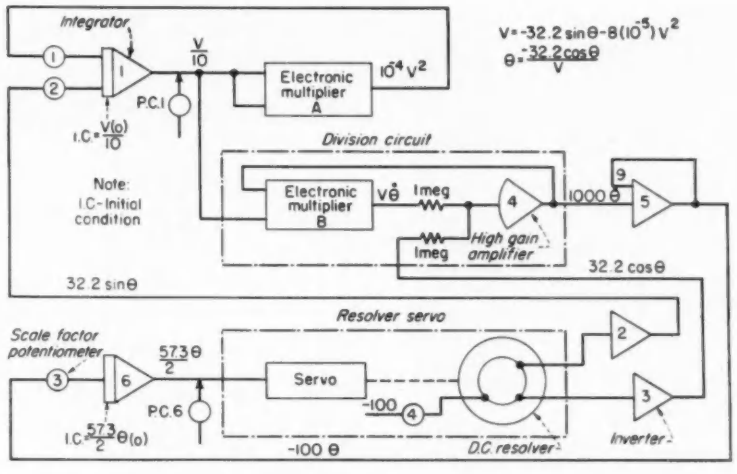


Sample problem shows how to use Problem Check. Outputs of integrators 1 and 6 are opened and simulated by PC1 and PC6 for static and dynamic checks. FIG. 2

PC1 and *PC6* are constant voltage inputs and cause voltages to appear at the output terminals of each computing element. All of these output voltages can be read and their values recorded. From the flow diagram and the equations, the correct value for each of these outputs can be calculated and compared with the measured values at Problem Check conditions.

For example, assume check conditions $v = 1{,}000$ fps and $\theta = \frac{1}{5}$ radian. Then the Problem Check potentiometers should be set so that $PC1 = 100$ v and $PC2 = 9.55$ v and the correct outputs are:

AMPLIFIER	OUTPUT FACTOR	VOLTAGE
1	$\dot{v}/10$	9.05
2	$32.2 \sin\theta$	10.5
3	$32.2 \cos\theta$	30.4
4	$1000\,\dot{\theta}$	−30.4
5	$-100\dot{\theta}$	3.04
6	$\frac{57.3}{2}\,\dot{\theta}$	0.87
Multiplier A	$10^{-4}v^2$	100.0
Multiplier B	$v\dot{\theta}$	−30.4

In cases where the mechanization includes nonlinear elements such as limiters and function generators, it may be necessary to verify computer operation at several check values.

PROBLEM CHECK DYNAMIC

Problem Check static verifies that all elements except the integrating condensers are functioning correctly. To check integration, the computer is put into Problem Check dynamic. All integrators then integrate for a fixed time, determined by a precision timer, and at the end of this time they are put automatically into hold. The output of each integrator equals a constant times the initial value of the derivative of the problem variable computed in the integrator.

For the sample problem, with a nine second integration time, these outputs are:

AMPLIFIER	OUTPUT FACTOR	VOLTAGE
1	$10\dot{v}/10$	90.5
6	$10\left(\frac{57.3}{2}\,\dot{\theta}\right)$	8.7

Note that the proportionality factor is ten instead of nine because each integrating condenser has an initial charge. The output voltages of the other computing elements are unchanged because the integrator outputs are still disconnected from the rest of the problem.

To facilitate computer operation during the check, an automatic digital recording system may be added. The output of each computing element can be scanned in turn by a stepping switch and, at each switch position, the voltage converted to digital form and printed out.

ADVANTAGES

Problem Check is analogous to code checking on digital computers. The problem is set up on prepatch boards away from the machine. In a relatively short time at the machine, the setup is "problem checked." The operator may then restudy the entire setup away from the computer, which can be used meanwhile on other problems. The check may be repeated as necessary without disturbing the problem setup.

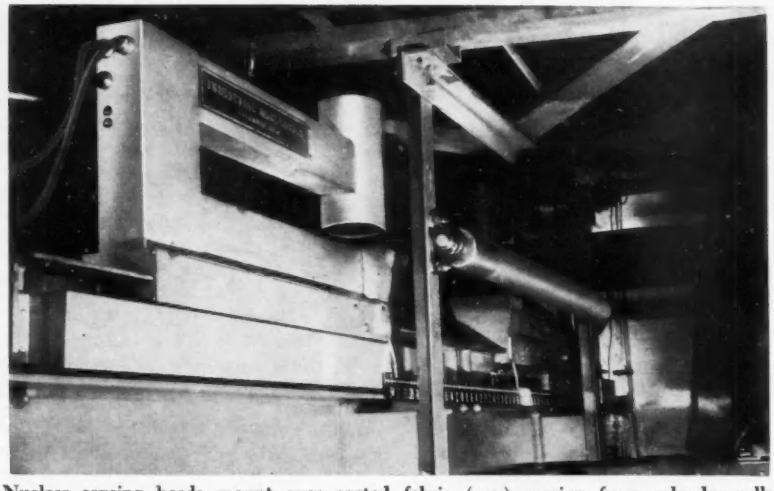
After the code is verified by Problem Check, runs may be taken on the computer with considerable assurance that the setup is correct and the machine is working properly.

The basic cost of Problem Check is one relay per integrator, one potentiometer per integrator, and one timer unit per computer.

(Ed. note:—Reeves has Problem Check in kit form for addition to existing REAC's.)

"Now, son, that control was good enough for my pappy an' good enough for me . . . Let's be cautious about this here auttymation."

NEW PRODUCTS



Nuclear sensing heads mount over coated fabric (rear) passing from calender rolls.

LISTING IN GROUPS

1 Nuclear Gaging Package
2-9 Digital Devices
10-13 Valves for Control
14-17 Instrument Parts
18-21 For Remote Control
22 31 Items for Measurement
32-34 Three Record Makers
35-43 Motors and Motion
44-49 Relays and Switches

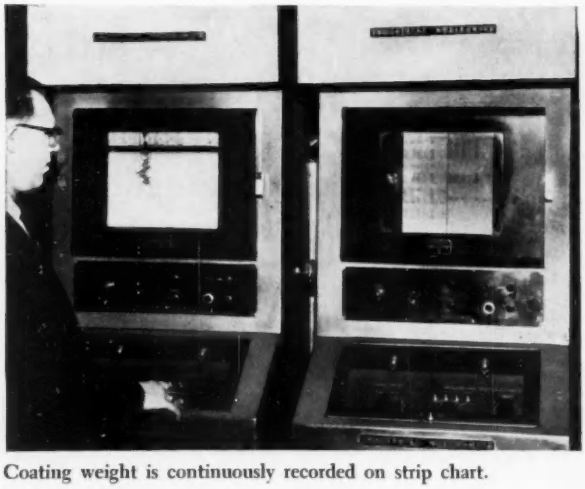
NUCLEAR GAGING COMES IN A CONTROL PACKAGE . . .

Last March CONTROL ENGINEERING ran a seven page article which described the flourishing growth of radioactive-type instrumentation since the war. The many letters from readers evidenced a strong industrial interest in this new tool. Now comes this packaged control system approach as further proof that nuclear gaging techniques are moving into practical closed-loop applications.

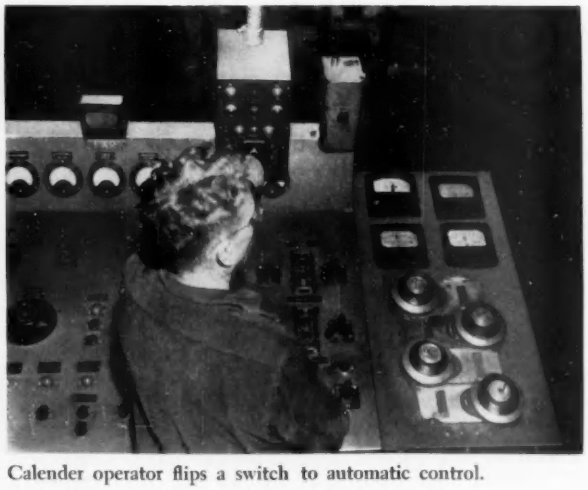
Actually, the three photographs on this page show the hardware for a specific system—the automatic control of a 4-roll inverted L calender at the Mansfield Tire and Rubber Co., in Mansfield, Ohio. The maker of the control system, Industrial Nucleonics, however, believes that its basic elements of continuous ray gaging of thickness and automatic adjustment of calender rolls can be fitted together for many other analogous industrial applications. Hence it has tradenamed the system "AccuRay" and offers it as a package to other users.

At Mansfield, "AccuRay" automatically adjusts the calender's bottom and offset rolls which simultaneously lay a top and bottom coating of rubber on tire fabric. The results, according to Industrial Nucleonics: more uniform tire fabric, material savings, and, a cooler running, better wearing tire for the public.

As shown in the top picture, two radiation-source measuring units are mounted at the point where the coated fabric moves over the calender. Variation in coating weight is picked up by proportional variation in radiation passage through the material. These variations are fed back to the strip chart recorders seen below. Above the recorders are associated control units that proportionately position the left and right side of the calender rolls. The recorders also



Coating weight is continuously recorded on strip chart.



Calender operator flips a switch to automatic control.

. . . AND IS AUGMENTED BY A NUMERICAL ANALYZER

register the exact weight of the fabric in passage.

Aside from continuous control action, charts from the system are analyzed by the Quality Control Dept. so that tolerance precision and production speed are held to a realistic ratio.

Augmenting the basic "AccuRay" system is Industrial Nucleonic's Production Analyzer, Model D-5—the black box pictured at the right. Essentially, this is a neat little computer that will numerically display the total production passing through the nuclear gage in terms of weight and thickness. It is also capable of classifying this production into three grades —premium, good, and reject—and tabulating plus or minus variations around a norm for good and reject.

Production figures show up on six digit counters on the display face of the unit. Measurement can be in feet or yards, or multiples thereof. Accurate tabulation has been done over a wide range of process speeds in various steel strip, rubber, paper, and plastic sheet forming operations. *Industrial Nucleonics Corp., 1205 Chesapeake Avenue, Columbus 12, Ohio.*

Circle No. 1 on reply card

CALIFORNIA SPAWNS FOUR MORE DIGITAL DEVICES

TURNS TRACES INTO DIGITS and delivers to computers via punched tape, typed sheets, or punched cards.

OSCAR Model N converts oscillograph records into digital symbols. The unit's digital output is either in straight binary notation (from 0000 to 4,905 counts) or in decimal digits (from 0000 to 3,999). This can be programmed into automatic typewriters, paper tape punches, or punched card machines. The manufacturer claims an accuracy to within one count of full scale. Vacuum tubes have been eliminated in the design, which is said to embrace a new principle—a cylinder connection between the operator and the machine. The new machine is one more link in this company's unique and expanding line—see cut on the third page of this month's "What's New". *Benson-Lehner Corp., 2340 Sawtelle Blvd., Los Angeles 64, Calif.*

Circle No. 2 on reply card

PUNCHED TAPE data plotted graphically to three digits

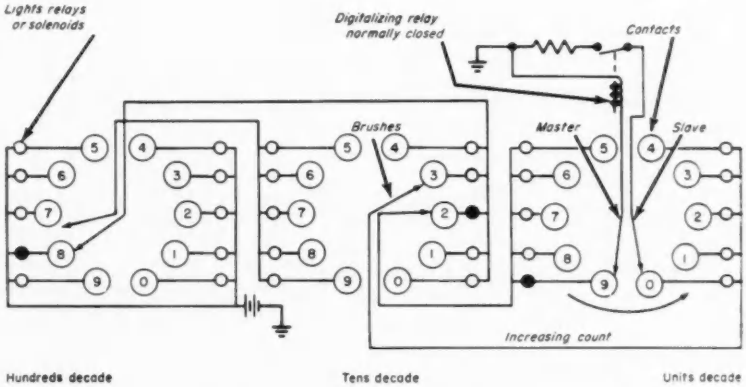
Punched tape now can operate an X-Y plotter. This puts it in the same league with a keyboard input, punched decimal IBM cards, and digital computers. While plotting from the tape goes on, an automatic typewriter, such as the Flexowriter, can put the data in printed symbol form. Nine symbols are required on the tape for each point plotted: a sign and three digits for each coordinate and a carriage return or "replot" signal. Ten symbols a second is the operating rate, but plotting speed limits actual plotting to one or two seconds per point. The converter contains 42 tubes. Librascope promises more machines of this sort, opening up the digital plotting game to whole fields of digital data storage systems. *Librascope, Inc., 1607 Flower, Glendale, Calif.*

Circle No. 3 on reply card

DIGITAL COMPUTER extends performance and capacity beyond previous models.

In the background here are three cabinets housing ALWAC III, the latest in a line of digital computers made for small organizations with large computations. The machine offers fast access storage of 128 words, and magnetic drum storage of 4,096 (on special order 8,192). Word length is 32 binary digits plus sign. Two of the 78 address instructions take the place of one word. A Flexowriter (punched tape input-output typewriter) or IBM card converter comes with the device. Incidentally, 90 per cent of its design is composed of six basic plug-in components. *Logistics Research, Inc., 141 South Pacific Avenue, Redondo Beach, Calif.*

Circle No. 4 on reply card



6-DECADE "DIGITIZER" CONVERTS shaft rotation to a million digital notations.

Joining the 3, 4, and 5 decade analog-to-digital converters of this company is a new 6 decade model, which will accumulate a total of 1 million counts at the rate of 10, 40, or 100 counts per turn of the input shaft. Its brushes can retract during rotation, allowing speeds of up to 18,000 rpm on the input shaft (3,000 digits per sec) and greatly reducing torque. Starting torque is 0.01 oz-in. Operation for continuous readout with the brushes and contacts engaged also is possible. Manufacturer declares this "Digitizer" is the first 6-decade instrument of its type, and suggests installation on data reduction equipment and comparators, in automatic control systems, and any other systems that require digital expression of a large number of shaft rotations. The instrument weighs 3 lb and fits in a case 7.4 by 5 by 1⅛ in. *Coleman Engineering Co., Inc., 6040 West Jefferson Blvd., Los Angeles 16, Calif.*

Circle No. 5 on reply card

STILL MORE DIGITAL DEVICES

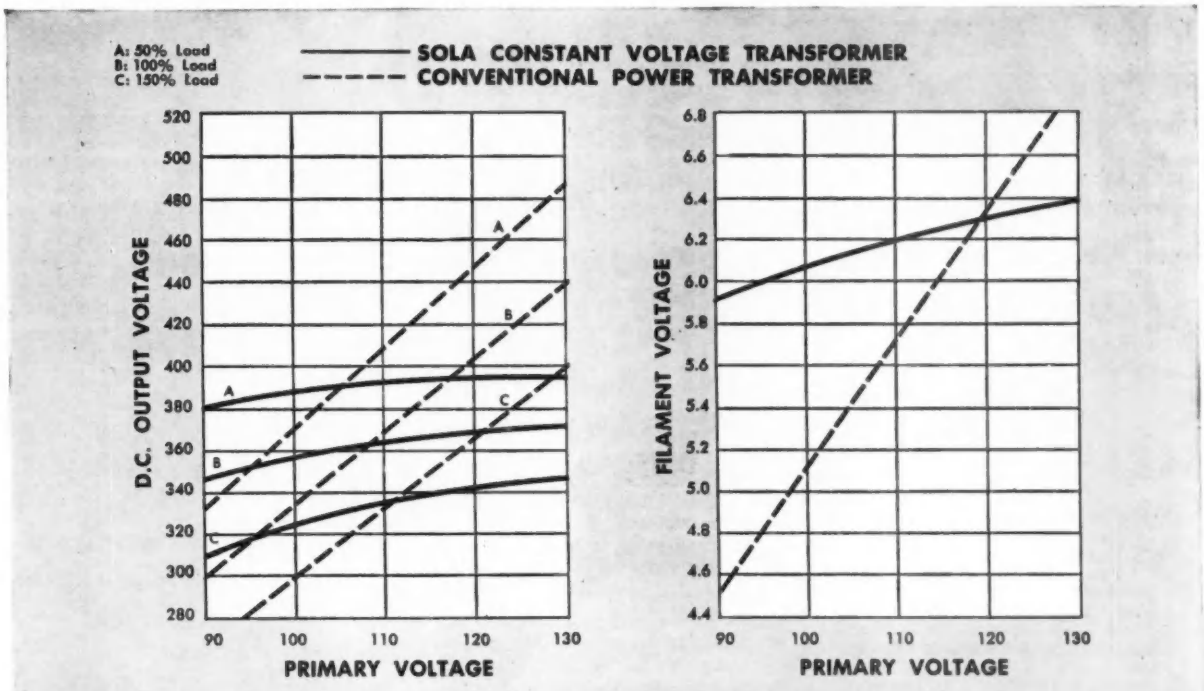
ANALOG TO DIGITAL trader converts to digital notation.

Maximum output of this little analog-to-digital converter is 13 natural binary bits and their complements. This makes a maximum output reading of 8,192, and without ambiguity, it is said. The high readout rate couples with readout "on the fly." The direction of rotation for increasing numbers can be changed simply by selecting appropriate output wires. The ADC-1A needs no translation equipment. It looks like something potentially dear to computer designers and those searching for a digital transducer output. *Norden-Ketay Corp., 555 Broadway, New York 12, N. Y.*

Characteristics

Size.....1¾ in. diam by 2¾ in.
Readout rate.....10^6 per sec.
Weight.....7 oz.
Moment of inertia.....9 gm-cm^2
Contact rating....35 v at 5 milliamps
Driving torque.....0.2 oz-in.

Circle No. 6 on reply card



These curves contrast the plate and filament supply voltages obtained from a Sola and a conventional power transformer when line voltage is varied from 100v to 130v.

Improve performance of control components with built-in regulating power transformer

You can make sure your product will always receive correct plate and filament voltages by building in a Sola Constant Voltage Power Transformer (Type CVE) in place of a conventional, non-regulating power transformer.

The Sola CVE provides ±3% regulation of plate and filament supply, with line voltage variations of 100 to 130 volts. Regulation is completely automatic, continuous and substantially instantaneous (1.5 cycles or less). Sola CVE stabilizers have no moving parts or tubes, require no manual adjustments or maintenance, and are self-protecting against short circuits.

Three stock units (all with high voltage ct, 5.0v and 6.3v regulated windings) are stocked by your electronic distributor. You can order production quantities of special units manufactured to your specification. We invite your inquiry.

TYPICAL STOCK UNIT: Sola Electronic Power Transformers are made for chassis mounting. They are furnished complete with separate capacitors and capacitor mounting brackets.

Automatic, Maintenance-Free Voltage Stabilization

SOLA *Constant Voltage* **TRANSFORMERS**

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CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • **LIGHTING TRANSFORMERS** for All Types of Fluorescent and Mercury Vapor Lamps. • **SOLA ELECTRIC CO.,** 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • BOSTON: 272 Centre Street, Newton 58, Massachusetts • NEW YORK 35: 103 East 125th Street • LOS ANGELES 26: 2025 Sunset Boulevard • PHILADELPHIA: Commercial Trust Building • CLEVELAND 15: 1836 Euclid Avenue • KANSAS CITY 2, MISSOURI: 406 West 34th Street • Representatives in Other Principal Cities

Aerohm Precision wire-wound Potentiometers

"Lo-TORK" POT LT ⅞

For minimum-torque uses in computer, servo, and selsyn service. Stainless-steel precision ball bearings. Maximum torque is 0.01 inch-ounce. Dissipates one watt at 80°C. Resistances—100 to 100,000 ohms. Weight is only ½ ounce. Ganging to six decks; internal clamps hold ⅜" diameter. Standard linearity 0.5%; on special order 0.25%; toroidal winding allows winding angles to 360°; standard 354°.

MICRO-MINIATURE and MINIATURE

Series AP ½-S—2 watts continuous at 80°C; resistances 10 to 20,000 ohms, 5% tolerance standard; diameter ½", depth ⅜", weight ¼ ounce; sealed well enough for potting.

Series RT ⅞-S—3 watts continuous at 80°C; resistance 10 to 100,000 ohms; diameter ⅞", depth ⅜", weight ½ oz.; standard linearity 2%.

Series AP 1⅛-S—4 watts continuous at 80°C; resistances 10 to 150,000 ohms; diameter 1⅛", depth ½", wt. less than ¾ oz.; standard linearity 1%.

All precision-machined, with anodized aluminum bodies line-reamed phosphor bronze bearings, centerless-ground stainless steel shafts, and gold-plated fork terminals. Fully sealed and fungus-proofed. Can be processed, on special order for use at 125°C. Aerohm potentiometers are individually checked for quality and performance.

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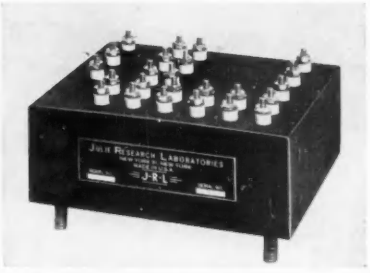
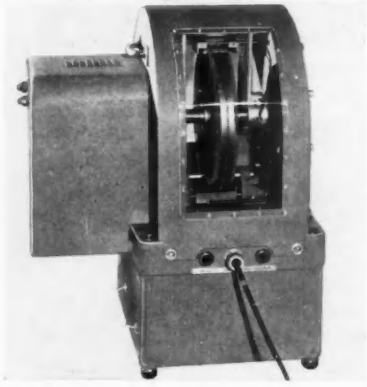
NEW PRODUCTS



DIGITAL TO ANALOG through small resistance steps.

This little box is designed for general computers and as a digital to analog converter. It contains a group of resistors that can yield accuracies on the order of 2 ohms in 131,070. It gets to that value in 2 ohm steps. For settings above 3,000 ohms, any value can be achieved with an accuracy of better than 0.01 per cent. Temperature stability is within five parts per million per degree C at 20 deg. Trick behind the little machine is the initial accuracy of 0.0015 per cent built into each resistor, which is associated with mates that watch over temperature effects, etc. The manufacturers call it the Binary Multi-Resistor, BMR-105. *Julie Research Laboratories, 341 East 149th Street, New York 51, N. Y.*

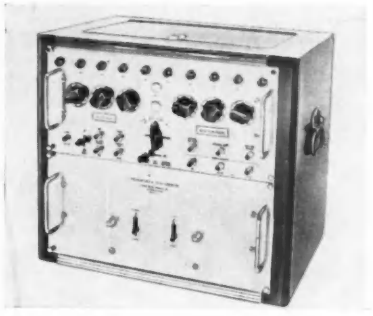
Circle No. 7 on reply card



PROCESS MEMORY links properties of moving material with meter readings.

The functions of this Proportional Syncronizer are clever indeed. Example: a steel strip, rolled into tubing and then welded, is gauged for thickness some time before the actual welding takes place. The Synchronizer stores in its "memory" the sheet thickness reading and later this information is read out to control the current of an arc welder. The time between input and output of the memory data equals the time for the measured material to pass from the measuring point to the welding point. Actually, the unit is constantly synchronized with the progress of the material. The synchronizer also functions as a coating measurer. The first reading stored is the thickness of the stock, the second the thickness of the stock plus coating, and the third, obtained by subtracting the first reading from the second over the same point on the material, is the coating thickness alone. *Pratt & Whitney Div. of Niles-Bement-Pond Co., West Hartford 1, Conn.*

Circle No. 8 on reply card



PRECISION DELAYS with 3,000-frequency oscillator-counter.

A thermostatically controlled crystal gives this Precision Digital Delay Generator an accuracy of 0.001 microsecs in 1,000 microsecs. It can check its own accuracy, manufacturer says. Operating continuously or on a one-shot basis, the relay's 3,000 basic frequencies, between 20 cps and one megacycle, make delays accurate to one part in a million of the timing frequency. *Kaiser Metal Products, Inc., Bristol, Pa.*

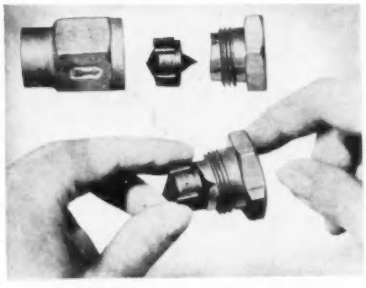
Circle No. 9 on reply card

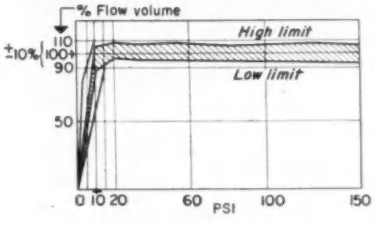
FEEDBACK FACT

Posed: Some way to speed up "shots" before the dangerous season.

Solved: The Army unites word with action. Its new vaccinator is pistol-shaped, triggers the stuff into you at 250 psi before you can say ouch.

VALVES FOR CONTROL





ONE MOVING PART and no springs in this flow control.

Simple enough is this flow-control. One moving part, a molded Neoprene diaphragm, is flexed to provide control through 0 to 150 psi of line pressure. The control's 21 flow rates, from 0.2 to 8 gpm, are held accurate to better than 10 per cent of the desired value. The figures are based on use with water. Three pipe sizes, ¼, ⅜, and ½ in., are on tap. *Hays Mfg. Co., Dept. 235, West 12th Street, Erie, Pa.*

Circle No. 10 on reply card

MINIATURIZED THROTTLING valve three operating modes.

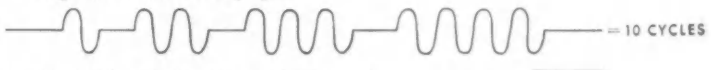
Direct or reverse action, top mounted positioners, and handjacks are available with this 6 in. high automatic diaphragm control valve newly

CYCLONOME

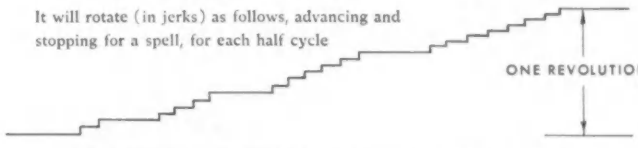
A device which converts electrical cycles into shaft positions, or, **a stepping motor.** You could also quite accurately say it's a very synchronous motor that works in jerks.

It has one moving part, a toothed wheel, that makes no contact with anything else except ball bearings. The ratchet and stepping effects are accomplished magnetically in air gaps. Like a synchronous motor, it operates on reversals of a magnetic field.

If energized with the following signal:



It will rotate (in jerks) as follows, advancing and stopping for a spell, for each half cycle



Note that each full cycle produces 2 jerks, and that 10 full cycles produce 1 revolution.

20 jerks per revolution is below par for a Banana Republic, but works out handily for decade style counting, and cycles are nice and binary if you look at them with an alternately biased viewpoint.

These gadgets are useful for all sorts of counting*, stepping and positioning, and can be used as high-torque instant-start synchronous motors. We're experimenting with printed-circuit 10- and 20-throw wafer switches with up to 4 decks or poles, by means of which schemes like telephone dialing can be done very fast and quietly.

We don't understand about computers and bigits and ring circuits any more than we do about automation, so you'll have to settle for what we know about the Cyclonome—if you can use it, fine.

**As in Sigma Cyclonome Pulse Counter.*

TECHNICAL SPECIFICATIONS

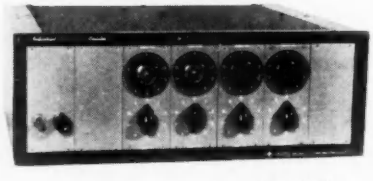
	TYPE 12A	TYPE 13A
Size	1-7/8" x 1-7/8" x 2-3/8"	1-7/8" x 2-5/8" x 2-3/8"
Torque	1.3 inch/oz.	2.6 inch/oz.
Inertia (Equal loads will reduce max. speed 70%)	.6 gram/cm²	1.2 gram/cm²
Max. speed, stepping	150 cps (15 r.p.s.)	
Max. speed, synchronous	600 cps (60 r.p.s.)	

For ELECTRICAL INPUT REQUIREMENTS, see bulletin for which please write.

Type 12A Cyclonome made with Lucite plates showing magnetic circuit
Type 12A Cyclonome complete with torsional damper
SIGMA

SIGMA INSTRUMENTS INC., 69 PEARL STREET, SO. BRAINTREE, BOSTON 85, MASS.

for PRECISE CONTROL:
for AUTOMATIC CONTROL:
equip your production lines with
ATOMIC'S
fast, rugged, reliable,
PRE-SET COUNTER-CONTROLLERS



Model 8684

features:

- Count items, events or units of process flow up to any pre-selected number
- Visually display the progress of every count
- Provide electrical control of any external function when pre-set count is reached
- Handle continuous or random counts
- Various counting rates available, up to maximum of 20,000 counts per second, according to model
- Available in single or dual pre-set types for control at one or at both of two chosen quantities
- Manual or automatic re-cycling

A wide range of models, both pre-set and totalizing, are available through unique unitized design. Models are described in the new Industrial Count and Control Systems Bulletin – write for your copy.

ATOMIC INSTRUMENT COMPANY
CAMBRIDGE 39, MASSACHUSETTS, U. S. A.

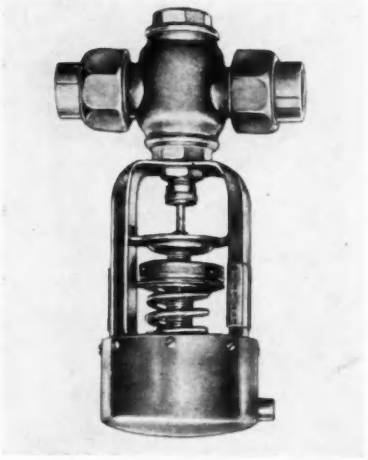
NEW PRODUCTS

added to maker's "Bantam" line. There are five sizes (⅜ in. and below) of linear, equal percentage, or quick opening plugs. *George W. Dahl Co., 430 High Street, Bristol, R. I.*

Characteristics

Control pressure.....3 to 15 psi
Weight .....3½ lb
Pressure rating.....1,000 psi
Temperature range.....to 350 deg. F

Circle No. **11** on reply card



BELLOWS-DRIVEN motor valve fits several systems.

Manufacturer declares that this bellows motor valve, the No. 992-D, feels at home in both hydraulic and pneumatic control systems and that this makes it a satisfactory component for more than 50 per cent of industrial applications where motor valves are used. It has linear valve movement for sizes ranging from ¼ to 4 in. and comes with a variety of valve types, including direct or reverse acting. *Fulton Sylphon Div. of Robertshaw-Fulton Controls Co., Box 400, Knoxville, Tenn.*

Circle No. **12** on reply card

POPPET-TYPE solenoid valve dispenses with spring.

Spring-action is eliminated and moving parts reduced to three in this new four-way poppet type valve. A dual solenoid, one of two models available, locks into position if power fails. Standard, water-tight, or explosion-proof models are outlined in the company's Bulletin 8344. *Automatic Switch Co., 391 Lakeside Avenue, Orange, N. J.*

Characteristics

Cycle rate.....850 per min.
Pressure.....500 psi or 250 psi
Power .....10 watts
Pipe sizes.....⅜, ½, ¾ and 1 in.

Circle No. **13** on reply card

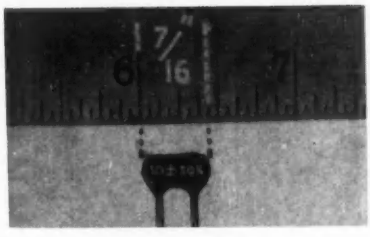
INSTRUMENT COMPONENTS

CHOPPER for 400 cps vibrates better than 2,000 hours.

Hermetically sealed for altitudes up to 50,000 feet, this chopper will withstand 100 g mechanical shocks and vibrations of 0.06 in. total travel from 10 to 55 cps. The single-pole double throw contacts take a milliamp at voltages ranging from 0.1 millivolts to 100 volts. The switching phase angle

of the chopper, driven at 6.3 v, 400 cps, is 65 plus or minus 15 deg, with dwell time on each pole 145 plus or minus 20 deg. It is said to have better than 2,000 hours of life. Coil impedance: 230 ohms. *Airpax Products Co., Middle River, Baltimore 20, Md.*

Circle No. 14 on reply card



WORLD'S SMALLEST capacitor carries leads side-by-side.

Said to be the first mica capacitor with parallel leads, as well as the world's smallest, this dipped DM-15 is rated from 1 to 510 mmf at 300 vdc and up to 400 mmf at 500 vdc with tolerances of ½ of one per cent. Fractional increases in overall size for capacities of up to 5,100 mmf distinguish the company's DM-19 and DM-20. *Electro Motive Mfg. Co., Willimantic, Conn.*

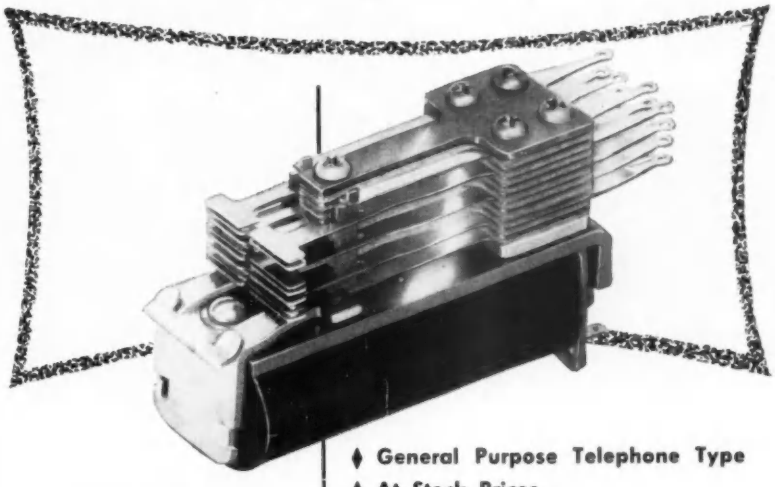
Circle No. 15 on reply card

GALVANOMETER AND ITS light beam all in one box

Shock resistant and sensitive up to 0.105 microamps per millimeter division, these light beam galvanometers come in housed assemblies that include lamp and projection system. By folding the light beam, the effective length in this fist-sized package is 80 mm. Not least important of its characteristics is resistance to 25 g shock. *Howell Instrument Co., 1106 Norwood, Fort Worth, Texas.*

Circle No. 16 on reply card

Kellogg provides custom assembled relays for industry



SPECIFICATIONS

COIL—Single or double wound.
ARMATURE—Frictionless armature travel. Both knife edge and hinged pivots.
OPERATING VOLTAGE—Up to 115 volts, D.C.
OPERATING TIME—From 2 to 30 milliseconds.
RELEASE TIME—From 5 to 50 milliseconds.
RESIDUAL—Fixed (clip) or adjustable (lock screw).
CONTACTS—Twin bar-dome type palladium contacts.
CONTACT ASSEMBLY—Forms A to D. Maximum of 16 A's, 14 B's, 10 C's, 10 D's or any equivalent combination of these contacts.
MOUNTING—Two No. 8-32 tapped holes in heelpiece allow versatile mounting.

- **General Purpose Telephone Type**
- **At Stock Prices**
- **Life Expectancy— Over 100 Million Operations**
- **1710 Contact Spring Combinations**
- **100 Stock Coils Available**
- **Precious Metal Contacts— Palladium or Gold Alloy**
- **Delivery 20 to 45 Days**

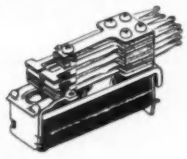
Variations of Relays available at Kellogg:

TIME DELAY RELAYS
TWIN RELAY—2 relays in space of one
SNAP ACTION RELAY
MULTI-CONTACT RELAY
PLUG-IN RELAY

KELLOGG — Division of IT&T

A famous name in communications now solving problems in the control industry

INDUSTRIAL SALES DEPARTMENT
KELLOGG SWITCHBOARD AND SUPPLY CO.
A Division of International Telephone and Telegraph Corporation
Sales Offices: 79 West Monroe Street
CHICAGO 3, ILLINOIS



KELLOGG SWITCHBOARD AND SUPPLY COMPANY
79 West Monroe Street, Chicago 3, Illinois Dept. 72-G

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☐ Please send detailed Relay information.

NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

TIMETER
solves
TIME-RECORDING
problems!

3-5/16" wide by
3-5/8" high by
2-5/8" deep.
Black bakelite molded case.

TIMETER automatically records operating time of electrically operated equipment; furnishes accurate records for time study, cost analyses; checks test runs, lamp and tube life; ferrets out lost man- and machine-hours. Operates independent of load. Rating: 100-125 volts, 60 cycles, 2 watts, A.C. Transformer or resistor supplied for higher voltage. Registers by 10ths of hours or minutes to 999.9 then repeats. Available up to 99,999.9 hours or minutes. Re-set feature optional. Write for data, prices.

TYPICAL APPLICATIONS

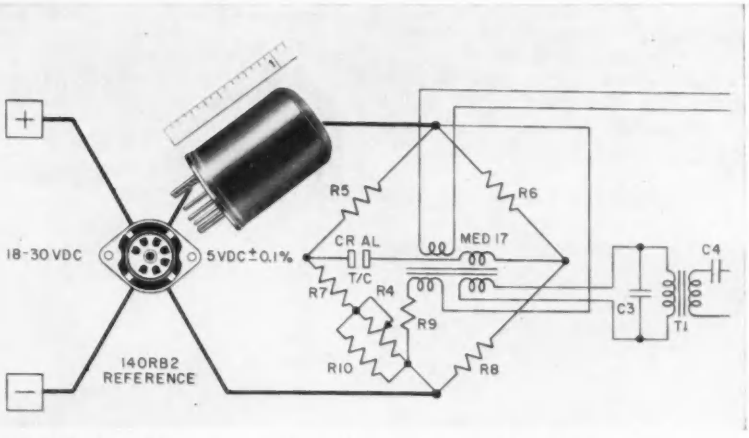
- Light & Power Circuits
- Industrial Equipment
- Leased Machinery
- Motor Driven
  - Stokers
  - Presses
  - Machine Tools
- Generators
- All types of production machinery
- Elevators

CAPEWAY INSTRUMENT CORP.

HIGHLAND AVENUE PLANT

EAST BRIDGEWATER, MASS.

NEW PRODUCTS



CONVERTS 20% supply instability to 0.1% in the output.

Above is a dc reference voltage source. Variations of 20 per cent in several supply voltage sources (24 vdc, or 110 vac, 400 cps, or other styles) will result in variations of only 0.1 per cent in the 5 v output. The maximum temperature drift claimed is 0.01 per cent per degree C for the minus 55 to plus 125 deg range. The 5 v output appears across a 5,000 ohm load. *Aircrafts Products Div., Manning, Maxwell & Moore, Inc., Danbury, Conn.*

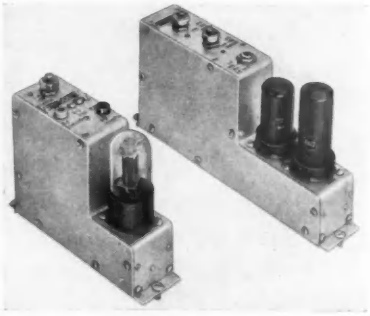
Circle No. 17 on reply card

FOR REMOTE CONTROL

CONTROL TOWER recorder keeps tabs on plenty of talk.

Intended for use in recording airport control tower talk with aircraft, this apparatus contains five tape recorders, each with alarm sections, timing signals, and cartridge loading. The playback is separate, and, to quote the information supplied by its Canadian manufacturer, "will most usually be located under the control of a superior officer and can be moved into a 'court of enquiry' in the presence of bodies intent on listening to the recorded evidence in the event of a crash." *Sonograph Engineering & Mfg. Co., Ltd., 122 Laird Drive, Leaside, Ontario.*

Circle No. 18 on reply card

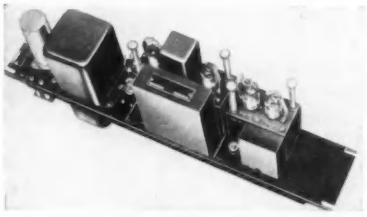


THESE TWO UNITS provide complete tone channel.

One tone oscillator and its companion tone detector, shown here, are all you need for a complete tone signaling channel for remote control, telemetering, etc. Any number, says the manufacturer, can be operated to-

gether over the same channel. Available frequencies: 500 to 6,000 cps. *Pacific Div. of Bendix Aviation Corp., 11600 Sherman Way, North Hollywood. Calif.*

Circle No. 19 on reply card



TONE CONTROLS feature up to 48 on-off functions.

Up to 48 on-off functions can be controlled over a single circuit by these Audio-Tone signaling units. Their range: 425 to 6,025 cps in intervals of 100 or 150 cycles. Audio Tone generators and receivers are plugged into the units. The frequency determination element of the generator and the filter of the receiver are small, separately mounted units. *Hammarlund Mfg. Co., Inc., 460 West 35th St., New York 1, N. Y.*

Circle No. 20 on reply card

TELEMETERING SWITCH scans and controls under strain.

Silver contacts bonded in Mycalex

First in performance for automatic muscle jobs like these...

T-J Spacemaker CYLINDERS

OFF SHELF DELIVERY

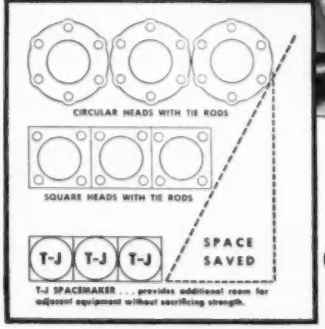
PUSH

PULL

LIFT

- OIL pressure to 750—AIR to 200 P.S.I.
- New Compact Design . . . Saves up to 40% Space
- Proven Performance . . . with Extra High Safety Factor
- Super Cushion Flexible Seals for Air . . . New Self-Aligning Adjustable Oil Cushion
- Hard Chrome Plated Bodies and Piston Rods
- The Only Cylinders with all the Extras as Standard

T-J Spacemaker Cylinders get first call for an ever-widening range of power movement jobs in industry today—because they're so advanced in design . . . so efficient and dependable in performance. Wide selection of styles and capacities. Check your needs now! Send for bulletin SM-454-2. The Tomkins-Johnson Co. Jackson, Mich.


CIRCULAR HEADS WITH TIE RODS
SQUARE HEADS WITH TIE RODS
T-J
T-J
T-J
SPACE SAVED
T-J SPACEMAKER . . . provides additional room for adjacent equipment without sacrificing strength.

Raise	Open
Lock	Time
Brake	Blank
Press	Cut
Spin	Broach
Turn	Drill
Grind	Sequence
Weld	Close
Lower	Snub
Squeeze	Form
Bend	Pierce
Coin	Feed
Saw	Mill
Tap	Convey
Index	etc.
Braze	

Member of the National Fluid Power Association

T-J TOMKINS-JOHNSON

RIVITORS AIR AND HYDRAULIC CYLINDERS CUTTERS CLINCHORS

THE MOSELEY

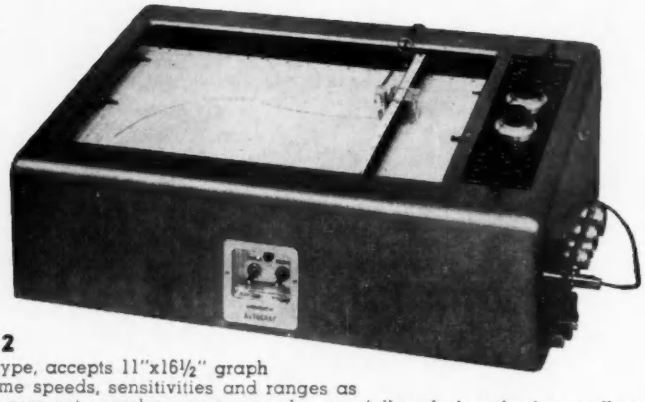
AUTOGRAF

trade mark

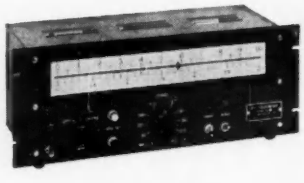
X-Y RECORDER

MODEL 1. drum type, accepts 8½"x11" graph paper; traverses each axis in 1 second; has full scale ranges of 5 millivolts to 100 volts; zero set anywhere on the paper; portable, self-contained; available also as a curve follower for electrical read-out of drawn curves.

AUTOGRAF Recorders, MODELS 1 and 2, provide all the features needed for graphic recording of test data, point plotting, and curve following for readout purposes.

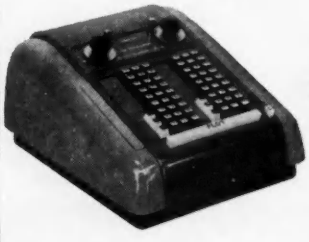


MODEL 2
Flat bed type, accepts 11"x16½" graph paper; same speeds, sensitivities and ranges as MODEL 1; zero set anywhere on paper plus one full scale length of zero-offset; inputs provided for analog recording, point plotting from digital sources, and curve following for computer or data reduction use.



MODEL 20 DC VOLTMETER is a servo-actuated, fast, accurate and sensitive instrument. Has large, easy-to-read scale for general laboratory use where ranges from 3 millivolts to 300 volts are desired. For data handling it is furnished with a built-in Coleman digitizer and delivers digital output for operation of printers, typewriters, tape or card punches, etc.

MODEL 30 CARD TRANSLATOR converts information from punched cards into point form for automatic plotting. Handles up to 50 cards per minute, 10 to 200 counts per inch. Plugs directly into MODEL 2 recorder, controls both card reader and recorder for completely automatic operation.



MODEL 40 KEYBOARD provides a convenient means for plotting large amounts of tabular data in point-curve form. Self-contained voltage source together with full three column keyboard in both X and Y axes; unit plugs directly into MODEL 2 AUTOGRAF.

Bulletins describing these instruments are available and we'll be glad to send them to you. Write . . .

F. L. MOSELEY CO., 409 North Fair Oaks Avenue, Pasadena 3, California

NEW PRODUCTS

410 are wiped at high speeds in this rotary telemetering switch. Clear signals have been maintained for more than 150 hours of continuous operation at 1,800 rpm. Manufacturer's tests indicate extended life at reduced speeds (1,500 hours at 600 rpm).

Mycalex declares that the switch, Model TM-55, operates reliably and without mechanical mis-alignment under adverse temperature (650 F max.), acceleration and vibration. Applications include remote control of guided missiles and relaying of flight data. *Mycalex Electronics Corp., Clifton, N. J.*

Circle No. 21 on reply card

ITEMS FOR MEASUREMENT

LOW MASS sensor ignores vibrations.

This low pressure pickup, type 4-315, can ignore vibration because of the low mass of its diaphragm. *Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 15, Calif.*

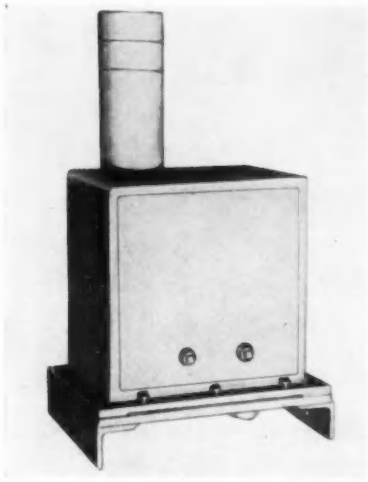
Characteristics

Size	1⅛ in. diam.
Pressure ranges	plus or minus 1, 2, and 3 psi differential
Sensitivity	plus or minus 10 mv with 5 v excitation
Error	plus or minus 1 per cent of full scale
Permissable overload	200 per cent

Circle No. 22 on reply card

GLOWING OBJECTS actuate this infra-red relay.

Industrial processes requiring information on the location or temperature of hot items will find use for this infra-red relay. A glowing cigaret at 10 feet will actuate the single pole double throw inclosed relay, the maker claims. Just plug it into 110 vac



wire to the three terminals of the relay's contracts, and you have the makings of a spectacular "no smoking" sign at the very least. *Industrial Gauges Corp., Englewood, N. J.*

Circle No. 23 on reply card

DIFFERENTIAL TRANSFORMER "package" includes contact-making meter.

This little box, with a built-in regulated differential transformer excitation, includes a relay-type meter with either high or low contacts or both for an on-off motion control circuit. The meter actuates a relay with 5 amp contacts. Maximum full-scale sensitivity of the meter is 0.030 in. using a "typical" differential transformer, or 0-5 lb using a Daytronic Series 140 Load Transducer. Price is near $300. *Daytronic Corp., 216 South Main Street, Dayton 2, Ohio.*

Circle No. 24 on reply card

EAD's
2" DIAMETER MOTOR
Makes Design easy as
1-2-3
1 one basic design
2 only 2" in diameter
3 three frequencies...60, 400 and variable
Here is one basic motor design incorporating the top-quality engineering that's "standard" at EAD . . . and capable of modifications for an unusually broad field of applications. You can order this 2" diameter motor (maximum weight is only 17 ounces) as an induction motor or a hysteresis-synchronous motor. It meets applicable MIL specifications and is available with Class "H" insulation for long life, high temperature operation. Just one more example of how EAD engineering meets the most exacting requirements for rotating electrical equipment.
INDUCTION MOTOR: For blowers, fans, automatic devices, business machines, control equipment, antenna drives, etc.
HP RPM AMPS MODEL
60 cycle, 115 volts 1/100 3,000 0.30 P52QDU
400 cycle 115 volts 1/100 7,200 0.30 P52QFU
1/50 7,000 0.40 P52NFU
1/30 6,200 0.80 P52LFU
1/50 22,000 0.75 P50NDU
320-1200 cycle variable frequency 1/300 4,500 av. 0.60 P52UFU
1/50 4,000 0.80 P52NEU
HYSTERESIS-SYNCHRONOUS: For timing devices; stroboscopic work; wherever load inertia is a problem (i.e. recorders, turntables, facsimile equipment, etc.)
HP RPM AMPS MODEL
60 cycle, 115 volts 1/200 3,600 0.26 P52SRU
Complete information on EAD's line of small motors and engineering - design service will be sent on request.
EASTERN AIR DEVICES, INC.
SOLVING SPECIAL PROBLEMS IS ROUTINE AT EAD
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375 CENTRAL AVENUE • DOVER, NEW HAMPSHIRE

KEARFOTT FLOATED RATE INTEGRATING GYROS

KEARFOTT 6.05 x 10^6 FLOATED GYRO

KEARFOTT 2 x 10^4 FLOATED GYRO

Consistently Accurate

Their initial accuracy represented by the random drift is continuously repeated in day-to-day operation.

ANGULAR MOMENT GM.CM.²/SEC.	MINIMUM DETECTABLE RATE	TYPE OF TORQUER	TORQUER LINEARITY FULL SCALE	CHARACTERISTIC TIME	DIMENSIONS	WEIGHT POUNDS
6.05 x 10⁶ 2 x 10⁴	.01°/hr. 4.1°/hr.	A.C.Vane A.C.Vane	0.175% 0.1%	.0035 Sec. .0025 Sec.	3-3/4" Diam. x 6-1/8" long 2" Diam. x 3-7/8" long	6-1/2 1-3/8

Kearfott 6.05 x 10^6 and 2 x 10^4 Floated Gyros have basic construction features that impart this all-important reliability. The materials used in their construction are of similar coefficient of expansion, thus avoiding mass unbalance due to temperature changes. Displacement information is provided by an extremely linear AC Vane pick-off. Either AC or DC torquers can be provided. Two additional floated rate integrating gyros, one with a 2.5 x 10^6 gm. cm.²/sec. wheel and the second with a 12.5 x 10^6 gm. cm.²/sec. wheel are available. Hermetic sealing provides resistance to extreme environmental conditions.

—Send for Technical Data Sheets

KEARFOTT COMPONENTS INCLUDE:

Gyros, Servo Motors, Synchros, Servo and Magnetic Amplifiers, Tachometer Generators, Hermetic Rotary Seals, Aircraft Navigational Systems, and other high accuracy mechanical, electrical and electronic components. Send for bulletin giving data of components of interest to you.

ENGINEERS:

Many opportunities in the above fields are open. Please write for details today.

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KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.

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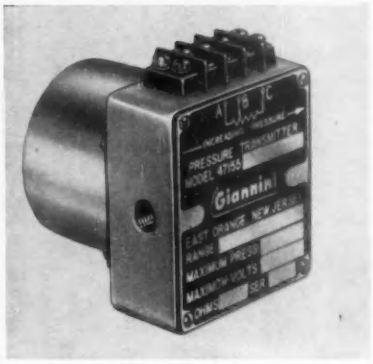
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

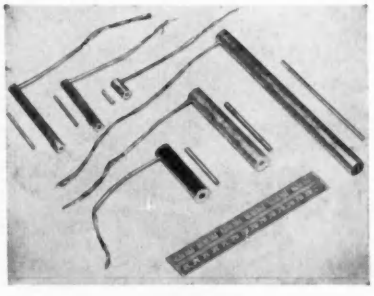
NEW PRODUCTS



PRESSURE TRANSMITTED by voltage signal via a pot.

Here is a low-cost version of Giannini Pressure Transmitter. It uses the principle of a potentiometer wiper positioned according to pressure Model 47155 and has ranges up to 100 psi, error down to 0.8 per cent, and sensitivity to 0.4 per cent. The pot winding is ½ watt at 2,000 ohms. As it puts out up to 40 v, recording without recourse to amplifiers often is possible. *G. M. Giannini Co., Inc., 918 E. Green St., Pasadena 1, Calif.*

Circle No. 25 on reply card

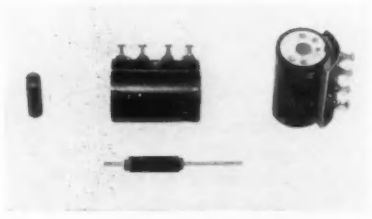


VELOCITY TRANSDUCER a polarized solenoid in reverse.

This pickoff, known as the LVsyn, generates an electrical signal proportional to the relative velocity of linear-motion elements. No external excitation is required. Sensitivity, independent of frequency of motion right up to the kilocycle range, is a function of the instrument's size. Its one-in. displacement range displays a ½ v per in. per sec motion. Its coil is well shielded. Principle of operation: a permanent magnet internal core, moving its field through a winding,

excites a voltage therein proportional to the speed of core motion. *Controls Components Co., 1 Holden Street, Brookline 46, Mass.*

Circle No. 26 on reply card



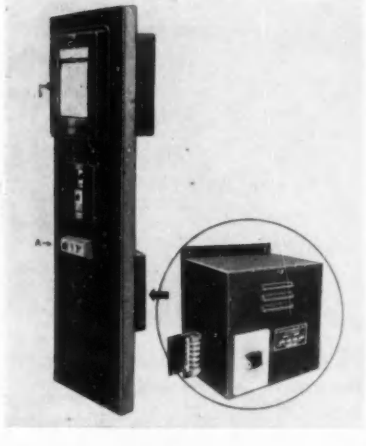
DIFFERENTIAL TRANSFORMERS convert minute motion.

Tapped holes or flat or screw lugs serve to mount two sizes of these differential transformers, formerly produced for Baldwin recorders only and now on the general market. Output is said to be linear to motion. The use of these Microformers to date has been in strain-gauge systems, one at the source balanced against a second in a recorder. *Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.*

Characteristics

Size	1¼ in. by ⅞ in. diam
Core travel	0.12 in.
Size	1 in. by ⅝ in. diam
Core travel	0.06 in.
Excitation	10 v or less

Circle No. 27 on reply card



SHOCK TREATMENT gets bugs out of thermocouple circuits.

Manufacturer claims this machine rejuvenates thermocouple systems upset by excessive resistance due to cor-

AFFILIATE OF GENERAL CERAMICS CORPORATION

Magnetic Amplifiers · INC

—announces its new

VARIABLE SPEED DRIVE

MAGNE-SPEED*

SIZE II — 3/4, 1 and 1-1/2 HP

SIZE I — 1/4, 1/3 and 1/2 HP

Stepless, instant starting, compact, 50:1 speed range, good regulation without tachometer, long life, virtually maintenance free service, low cost, fast response, reversibility, dynamic brake, local or remote control. Write for Bulletin S580-5-55.

Other MA Products and Services

Magnetic Servo Amplifiers
Transi-Mag * Amplifiers
Analog Computors
Photoelectric Controls
DC and AC Regulated Power Supplies

* Trade Name

Application engineering and conversion of tool machines and production processes to automatic control.

Magnetic Amplifiers • Inc

Tel. CYpress 2-6610 • 632 TINTON AVE., NEW YORK 55, N. Y.

Staggered starting of electric motors...

AGASTAT
Time / Delay / Relay

AGASTAT allows you to stagger the starting of three motors without imposing their load on the line at the same time.

The AGASTAT is
- electrically actuated, pneumatically timed.
- light, versatile, dependable.
- instantaneous recycling.
- adjustable in timing from 0.1 second to more than 10 minutes.
- available in AC or DC models which offer delays on energizing and de-energizing, manually-actuated time delay switch, remote push button control, hermetically-sealed units.

Write our application engineers for help with your timing problem. Address Dept. A25-720.

AGA DIVISION

Elastic Stop Nut Corporation of America

1027 Newark Avenue, Elizabeth, New Jersey
Pioneers in pneumatic timing.

Write today for your free copy of this Technical Paper.

ask for data file **710**

Characteristics of Precision Servo Computer Potentiometers

BY D. C. DUNCAN
General Manager, Helipot Corporation

Presented at A.I.E.E. CONFERENCE ON FEEDBACK CONTROL SYSTEMS

388

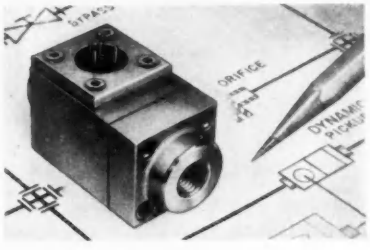
Helipot *first in precision potentiometers*

Helipot Corporation / South Pasadena, California
a division of BECKMAN INSTRUMENTS, INC.

NEW PRODUCTS

rosion, oil-soaking, or loose circuit connections. The cure consists of a special impulse that breaks down the unwanted resistance. Manual or automatic performance is available. *The Peerless Electric Co., Electronics Div., Warren, Ohio.*

Circle No. 28 on reply card



STRAIN SENSITIVITY gives voltage-pressure balance.

This device is a differential pressure pickup using the principle of a strain-sensitive resistance bridge connected to its diaphragm. Ranges up to 1,000 psi are being sold, with hysteresis errors of less than ¼ of one per cent and overall accuracy of ½ of one per cent full scale at 70 deg F. Ac or dc excited voltages and bridge resistances of 350, 600 or 800 ohms can create minimum full-scale outputs of 20, 40, or 50 millivolts, respectively. *Dynamic Instrument Co., Inc., 28 Carleton St., Cambridge, Mass.*

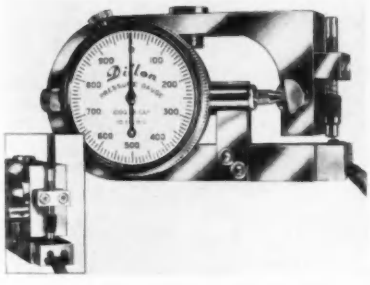
Circle No. 29 on reply card

TEMPERATURE LIMIT switch prevents overheating.

Snap acting on temperature differences of 15 deg or higher, these hermetically sealed temperature switches, Series C-4344, are destined to find use as high-limit temperature controls for motors, transformers, rectifiers, storage batteries, etc. Their range of preset actuation is 60 to 250 deg F for

125 to 250 v, and from 250 to 400 deg F for 30 v, ac or dc. *Spencer Thermostat Div. of Metals & Controls Corp., Attleboro, Mass.*

Circle No. 30 on reply card

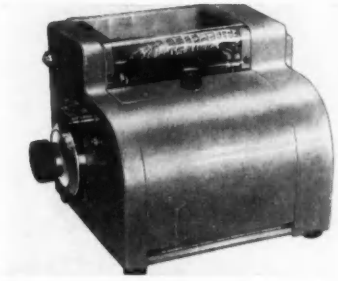


VISUALLY AND ELECTRICALLY indicates production.

Reflecting an amazingly simple idea is this mechanical pressure gauge carrying a microswitch. The gauge is sold in 10 ranges 0-10 to 0-10,000 lb, and the microswitch can be operated at any point on the scale. The gauge's warranted accuracy is to 1 per cent, and it withstands overloads of 25 per cent. Possible use in automatic production control: visual and electrical indication of the load on a conveyor, in a hopper, etc. *W. C. Dillon & Co., Inc., 4620 Keswick St., Van Nuys, Calif.*

Circle No. 31 on reply card

RECORD MAKERS



210 FIXED STYLUSES in basic recorder component.

Here's a package for the man with a system potentially outputting through a fixed-stylus recorder. Designed as a basic building block, it offers variable chart speeds from ¼ in. to 5 in. per sec., with 210 styluses writing on 5 in. wide paper contained inside in

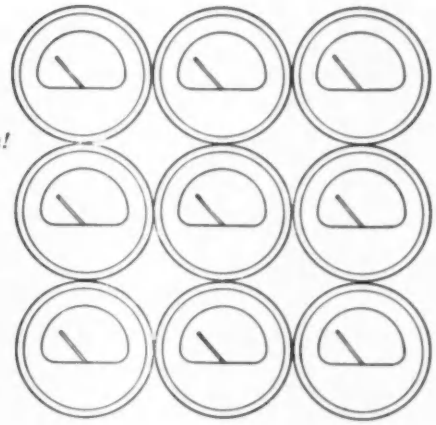
precision instruments by DeJUR

ACTUAL SIZE

There's "big meter" precision in this Series 100 SEALED SUBMINIATURE METER

Now you can specify this tiny, light weight instrument and still get ±3% accuracy over full scale. Special "O" ring and locknut provide watertight, single hole mounting. Complete technical literature sent on request.

9 Meters in Only 3¾" Square!



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DeJUR Sealed and Ruggedized Instruments: 1", 1½", 2½" and 3½". Send us your requirements and we will submit our quotations.

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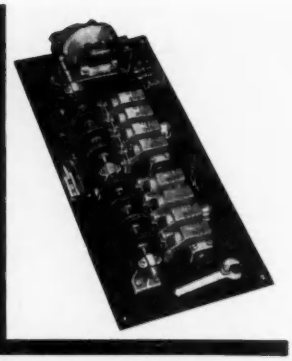
snap-action
at 1 to 80 psi.

flexible
sequence control

dependable,
simple, sturdy



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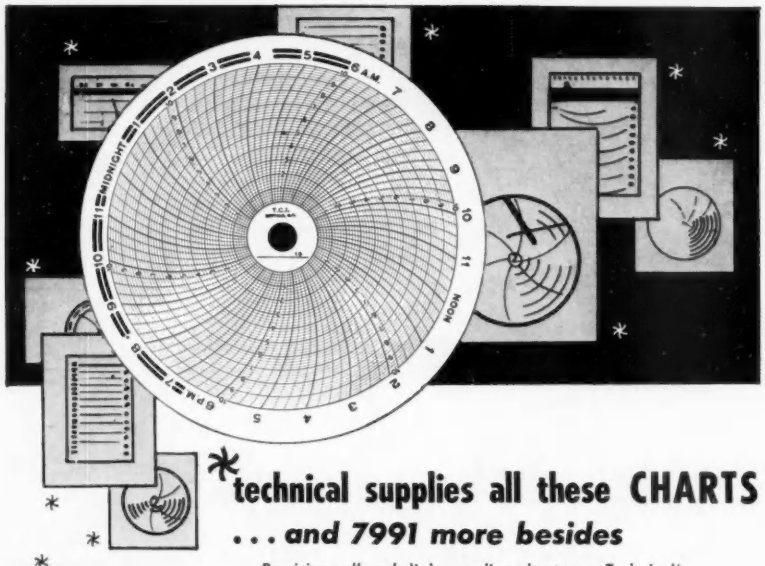
PNEUMATIC
TIMERS

Adjustment and change of sequence or cycle time is easy on ATC Pneumatic Cam Timers, custom-built from standard parts. Designed to operate at 3 to 15 psi. Minimum time setting is 1% of cycle; repeat accuracy, ¼%. Springless poppet—the only moving part of each valve—unaffected by over-pressuring to 100 psi, needs no lubrication. Stop-or repeat-cycle action.

Complete data in Bulletin N-101. Automatic Temperature Control Co., Inc., 5242 Pulaski Ave., Philadelphia 44, Pa.

Represented in Canada by: Powerlite Devices, Ltd., Toronto, Montreal and Vancouver



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Precision roll and dial recording charts are Technical's **only** products. This specialization means extreme chart accuracy . . . and big procurement savings as well. You can order any of more than 8000 different charts on one order. Automatic order processing and large inventories assure prompt deliveries. Catalog 55 explains services . . . shows chart samples . . . write today.

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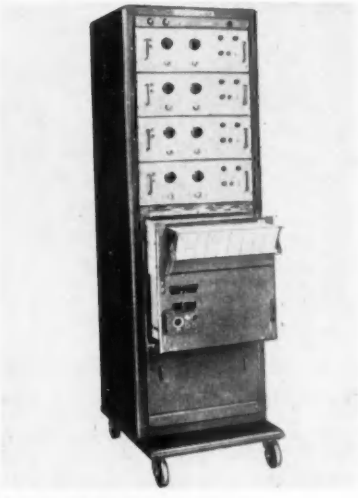
NEW PRODUCTS

100 ft lengths. The R-1021-1 is housed in a 9½ by 7½ by 8 in. case weighing 15 lb. *Radiation, Inc., Melbourne, Fla.*

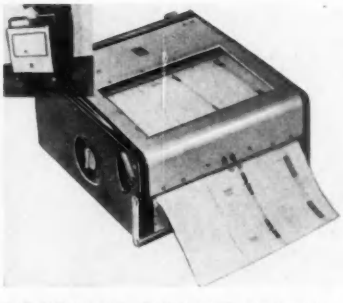
Circle No. 32 on reply card



HOT STYLUS records on six and eight channels.

Six and eight channels in this oscillograph recorder are provided with 1 volt/cm sensitivity, nine paper speeds, and all required circuitry. *Industrial Div. of Sanborn Co., 195 Massachusetts Avenue, Cambridge, Mass.*

Circle No. 33 on reply card



PORTABLE OSCILLOGRAPH records 4 or 6 channels.

Four channels in 36 lb and six channels in 48 lb. That just about describes two new portable oscillographs being offered by Brush. Each machine has 16 chart speeds, ranging from 10 in. per day to 10 in. per sec. Both 4 and 6 channel models record either electrically or in ink and both have remote control operation. *Brush Electronics Co., 3405 Perkins Avenue, Cleveland 14, Ohio*

Circle No. 34 on reply card

MOTORS AND MOTION

SYNCHRONOUS motor converts 60 cycle current into 420.

Converting 60 cycles into 420 is the job of this new Georator Corp. product, which employs a synchronous motor drive. The attached "No-brush" generator creates no radio interference, cannot be damaged by short circuits, and provides from 150 va to 5 kva. Georator stocks all standard output voltages, single or three phase. *Georator Corp., Manassas, Va.*

Circle No. 35 on reply card

SPEED SWITCH governor restrains rpm.

Rotating flyweights govern the tripping action of this three-element speed-sensitive switch. The governor opens or closes three snap switch circuits at three selected speeds from 1,200 to 10,000 rpm. Contacts are rated 10 amp at 115 vac. In a typical application in engine or turbine control system, the switch serves as automatic starter disconnect, and as underspeed and overspeed protection.

when toxic gases threaten...

Brooklyn-Battery Tunnel safeguards the public with Taller & Cooper's Carbon Monoxide Detector

TALLER & COOPER'S ADVANCED CARBON MONOXIDE DETECTOR is on the alert for you!

Accurate, efficient CO control is provided at low cost with the Taller & Cooper Carbon Monoxide Detector. It measures from 0 to 5 parts per 10,000 of CO in air and indicates *where* and *when* blowers should be turned on.

This eliminates the need for carbon monoxide control by continuous ventilation, which is both costly and inefficient. Blowers are turned on only when CO concentration reaches toxic level, and are turned off when CO has been blown away.

The T&C Detector thus gives maximum protection at minimum operating and maintenance cost—for only a few cents a day.

No special skill is required to operate it, and it may be used to control blowers directly for completely automatic protection. With slight modifications, the T&C Detector can be used to safeguard against combustible or explosive gases.

Write for Bulletin 201 and full details.

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- Control Equipment & Systems
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NEW!
REVERSIBLE DATA REDUCTION SYSTEM

Handles 200,000 Points per second!

- **MAXIMUM RELIABILITY . . . no electro-mechanical switching units to fail or service.**
- **MAXIMUM ACCURACY . . . temperature-stabilized standard cell array automatically calibrates voltage measurements.**
- **MAXIMUM LIFE . . . outlasts other converters by years of continuous operation.**

Now a brand new ultra-high-speed reversible data converter . . . DATRAC . . . automatically translates voltages to digital data or reverses the process.

Bulletin just released shows suggested DATRAC applications such as: engine test data translation; reduction of shaft rotation and thermocouple or strain gage information to digital form; precision analog recording and playback; machine tool and chemical process control; and many others. Also includes specifications of five DATRAC converter models. Send for your copy . . . TODAY!

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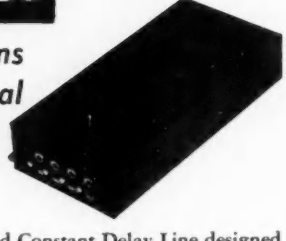
Brew Delay Lines

. . . for applications requiring exceptional characteristics



Shown above is a Lumped Constant Delay Line designed, manufactured, and *delivered on schedule* to a customer who came to us with the following requirements: delay 1.0 usec, reflections 50 db below peak signal, frequency response: from 0-4.5mc less than ± 0.1 db — from 4.5-10mc less than ± 6 db, attenuation less than 6 db, phasing ± .01 usec 0-4.2 mc, impedance 150 ohms, max. temp. 150° F., operating temperature 120° F., voltage 350 VDC ± 6 VPP video, source impedance 4 uu 1200 ohm, grid circuit termination 10 uu.

The three main types of delay lines . . . Lumped Constant, Ultrasonic, Distributed Constant . . . are available from Richard D. Brew and Co., and our special techniques and methods, plus rigid quality control measures assure you of the finest and most practicable delay lines to meet your needs. Major consideration is given to proper packaging as well as electrical specifications.

Consult Richard D. Brew and Co. and you'll get enthusiastic cooperation and help.

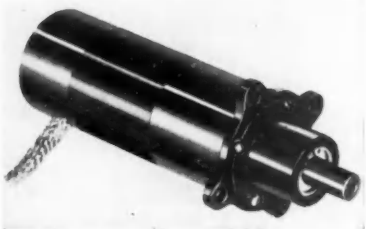
Send for General Catalog 54

BREW
Richard D. Brew and Company, Inc.
Concord, New Hampshire
design · development · manufacture

NEW PRODUCTS

Cut shows Model GA-3, with AND20005 engine tachometer drive pad; it also is available with flexible shaft, belt or chain-drive, and SAE distributor take-off. Plated or non-corrosive metals and waterproof or fungus proof construction, as desired, give environmental protection. *Synchro-Start Products, Inc., Skokie, Ill.*

Circle No. 36 on reply card



PM MOTOR reduces radio interference.

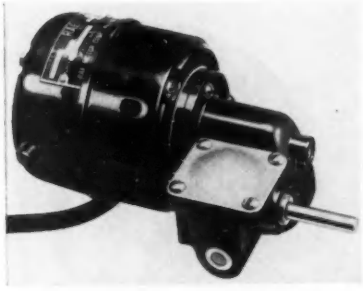
Permanent magnet motor constructed with shielded leads lessens radio noise. Applications include tuning devices, drive mechanisms, and antenna tiltmotors. The motor, designed to meet MIL-M-8609 specs, is available with combinations of gear train, governor, and brake. *John Oster Mfg. Co., Avionic Division, One Main Street, Racine, Wis.*

Circle No. 37 on reply card

ELECTRIC TACHOMETER displays fast action.

Speeds of up to 20,000 rpm convert to an electric signal in this new tachometer using the M-400B magneto direct-connected to a rotating shaft. Output of the magneto, wired to the electric tachometer indicator (DB-16), deflects the pointer. Calibrated in rpm or related functions, the system has an error of one per cent of maximum speed and a readability of one part in 400. The heavy-duty magneto uses precision bearings and built-in worn reduction gears. The indicator movement traverses 250 deg on an eight in. dial (17½ in. scale arc). *Electric Tachometer Corp., 2218 Vine Street, Philadelphia 3, Pa.*

Circle No. 38 on reply card



PARALLEL SHAFT gear reducer gives low speed.

Parallel output shaft highlights this G-8 gear reducer, which is adaptable to its various motors, gives shaft speeds as low as one rpm, and takes loads of 15 in.-lb. Model M-G-8 is illustrated. Electric governor speed control and brakes are available. *RAE Motor Corp., P. O. Box 291, Racine, Wisconsin.*

Circle No. 39 on reply card

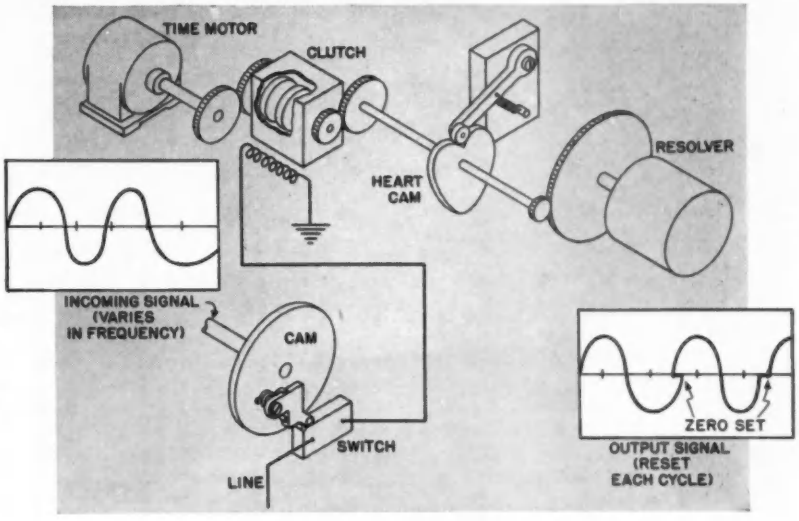
HYDRAULIC MOTOR controls own speed.

Built-in speed control simplifies the installation of Vickers Series MRO oil hydraulic motors. Design eliminates extra fittings, reduces leaks, and aids in maintenance. Other features: pre-set constant speed (plus or minus 5 per cent) from no load to full load; sizes from 2.3 to 18 hp; continuous speeds 6,000 rpm and intermittent up to 9,100 rpm.

Piston-type fixed displacement motor, together with valve plate and speed regulator valves, gives 96 per cent volumetric efficiency. It is engineered for continuous duty at 3,000 psi. Right-hand, left-hand, or reversible rotation are available. Setting relief valve protects motor during continuous, intermittent, or stalled operation. *Vickers, Inc., 1400 Oakman Boulevard, Detroit 32, Mich.*

Circle No. 40 on reply card

SINCE 1915 LEADERS IN AUTOMATIC CONTROL



HOW TO ZERO-SET RANDOM PHASE VARIATIONS

Many modern control devices are designed for applications where sensed input signals fluctuate randomly about an approximately known frequency. In some of these applications, the information is conveyed by the phase relationship within one cycle, and the random cycle-to-cycle phase variations often submerge the signal in noise. Filtering, or averaging, techniques may be extremely difficult to devise because of the requirement for use within one cycle.

The ingenious electro-mechanical solution shown above is a typical Ford answer to a difficult problem. It is rugged and reliable, yet compact and easy to service. In operation, a constant-speed motor drives a resolver at the required speed. The sensed input controls the operation of the clutch, and at each zero-crossing in the positive direction, decouples the motor from the line. At the same time, the spring-loaded heart cam follower resets the synchro shaft to its zero position.

In this manner, the resolver is reset to a prescribed phase relative to the signal at a fixed point of every cycle of the generated signal.

This is another instance of how Ford's engineering staff selects the most efficient device to solve a problem. Here at Ford mechanical *and* electronic devices are given consideration in solving any problem.

Since 1915 the engineers at Ford Instrument Company have specialized in such equipment as computers, controls, and servo-mechanisms in hydraulics, electronics, mechanics and magnetics for the Armed Forces and for industry. If you have problems in any of these fields, it will pay you to discuss them with Ford engineers.

67

FORD INSTRUMENT COMPANY
DIVISION OF SPERRY RAND CORPORATION
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Automation made easy

by a POTTER PREDETERMINED COUNTER

Potter Predetermined Counters deliver precise control of any process which can be counted or measured. Exact, errorless quantity, length, revolution, time or sequence may be counted at speeds of up to 60,000/minute. Relay control is provided at the predetermined counts with automatic or manual reset. Electronic design precludes inertia. Maintenance is negligible. In single, dual or multiple sequence counters.

If you have a control problem we'd like to offer our recommendations—please write or call.

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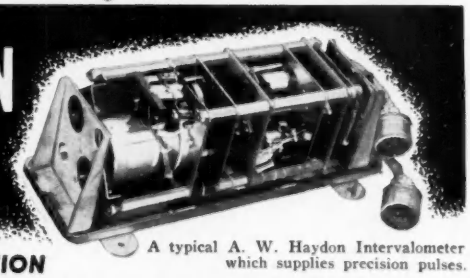
Short Interval Timing Your Problem?

A. W. HAYDON
CAN HELP YOU.



A typical A. W. Haydon Intervalometer which supplies precision pulses.

THREE TYPES OF OPERATION

The operator adjusts a selector switch to determine the type of operation.

OPTION #1. When a starting pulse of 100 Milliseconds is applied, this Intervalometer starts up and energizes 15 Pulsing Circuits at 50 Millisecond intervals. Each circuit is on for 30 Milliseconds. At the end of the period, the unit automatically resets to the starting position.

OPTION #2. When a starting Pulse of 100 Milliseconds is applied, this Intervalometer starts up and energizes 6 Pulsing Circuits, then shuts down. When the next starting pulse is applied, the balance of 9 pulsing Circuits are energized. The unit then resets to the starting position.

OPTION #3. When 1st starting Pulse is applied 5 Pulsing Circuits are energized. When 2nd starting Pulse is applied next 5 circuits are energized. When 3rd starting Pulse is applied next 5 circuits are energized.

WHEN TIMING POSES A PROBLEM CONSULT

WRITE FOR GENERAL CATALOG OR SUBMIT DETAILED PROBLEM STATEMENT.

The A. W. HAYDON COMPANY
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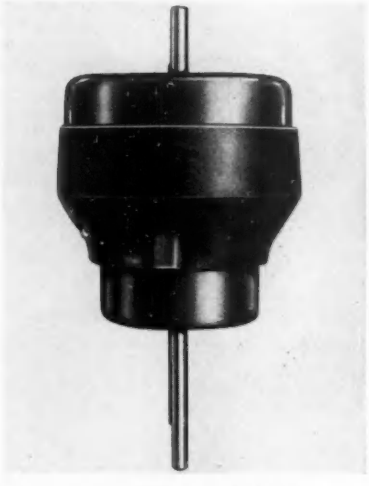
Design and Manufacture of Electro-Mechanical Timing Devices

NEW PRODUCTS



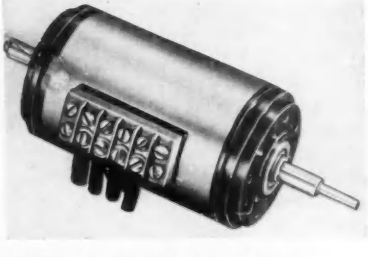
FRACTIONAL HP MOTOR circulates lubricant.

This shaded-pole motor contains two main features: unit bearing construction and a lubrication system using a viscosity pump and isolated cooling reservoir. The SP-25 motor runs quietly and has single or double shaft extensions. Stable speeds as low as 400 rpm can be attained at reduced voltage. *Electric Motors and Specialties, Inc., King and Hamshen Streets, Garrett, Ind.*

Characteristics

Output	1/60 to 1/30 hp
Speed	900 to 1,550 rpm
Input voltage	115 vac
Poles	4

Circle No. **41** on reply card



THERE'S VERSATILITY in this case of two clutches.

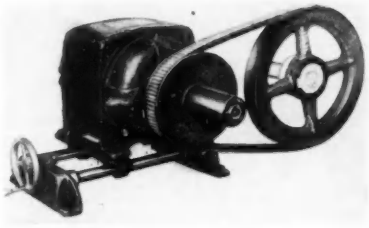
This idea of two clutches in a single case should please those servo system designers who must clutch two outputs independently from a single power shaft. The reverse, clutching one shaft onto either of two input rotations, can also be accomplished, of course. MK 8 Mod O servo motor

mounting is provided for model T508. *Instrument Div. of Sterling Precision Instrument Corp.*, 34-17 Lawrence Street, Flushing 54, N. Y.

Characteristics

Engagement time.....3 millisec
No slip torque.....35 oz-in.
Coils.....24 vdc, 3 watts
Backlash.....5 min, engaged
Size.....1¾ in. diam by 3⅛ long

Circle No. 42 on reply card



VARIABLE SPEED pulley controls moving machinery.

Speed control of machinery in motion is available in ratios up to 3 to 1 from this variable speed pulley. Finger-tip pressure adjusts 7½ to 15 hp in action—quickly correcting for process or production upsets. The pulley comes in a variety of arrangements:

	#310 vsp base	#315 vsp base
1150 rpm motor	7½ hp max.	10 hp max.
1750 rpm motor	10 hp max.	15 hp max.

Standard bores are 1¼, 1⅜, and 1⅝ in. diam. Other specifications include 13.1 in. maximum and 4.35 in. minimum pitch diam. *Lovejoy Flexible Coupling Co.*, 4948 W. Lake Street, Chicago 44, Ill.

Circle No. 43 on reply card

RELAYS AND SWITCHES

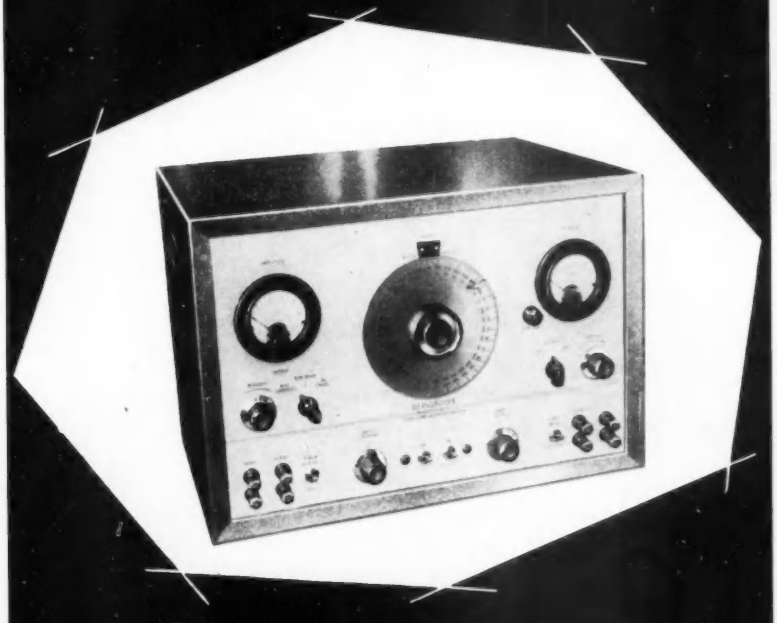
SPECIAL SWITCHES for particular applications.

From switches used in testing systems comes a new line, uniquely designed for special applications. Among them is this 81 position, 2 circuit model. It's for continuous rotation with voltage breakdown of approximately 1,500 vdc. More than 50,000

SERVOSCOPE®

the first
and still the finest
instrument of its kind
in the world

...no need to say more.



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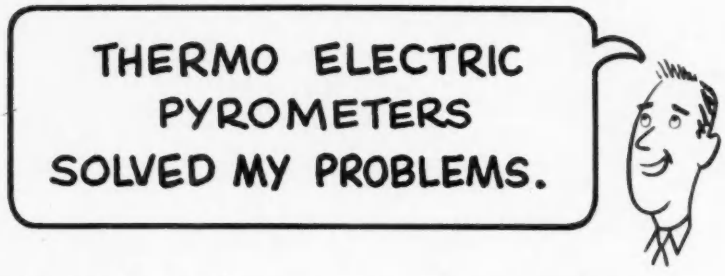


Thermo Electric makes many products that help solve problems in the field of temperature measurement and control. T-E controllers and indicating-recorders are good examples. They are both made in two types: potentiometer pyrometer and resistance thermometer. They are accurate (±¼ of 1% of the range), rugged, simple in design, easy to maintain. Ranges from −100°—+600°F up to 0—3000°F.

THERMO ELECTRONIC INDICATING-RECORDER

Only three moving parts in the recording system—pen arm is driven from a cam, which permits linear charts to be used for all temperature measurements—full scale pen travel only 4 seconds. Easily adapted to measure humidity, solution conductivity, speed, pH, direct current, DC voltage, or other variables.

THERMO ELECTRONIC CONTROLLER

Two-position control action is continuous and instantaneous — potentiometer pyrometer type is sensitive to changes of as little as ±1.5°F, or less; resistance thermometer type is sensitive to changes of as little as ±0.1°F.

Write for details:

controller, potentiometer pyrometer type, bulletin 50-B.
controller, resistance thermometer type, bulletin 55-B.
indicating-recorder, both types, bulletin 60-B.

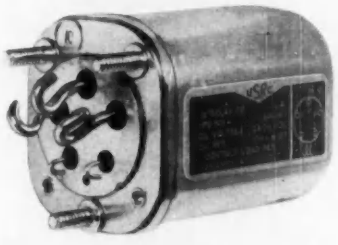
Pyrometers • Thermocouples • Protection Tubes • Quick-Coupling Connectors
Thermocouple and Extension Wires • Resistance Bulbs • Connector Panels

Thermo Electric Co., Inc.

SADDLE RIVER TOWNSHIP, ROCHELLE PARK POST OFFICE, NEW JERSEY
IN CANADA—THERMO ELECTRIC (Canada) Ltd., BRAMPTON, ONTARIO

operations are said to be typical life. *Industrial Instruments, Inc., Cedar Grove, N. J.*

Circle No. 44 on reply card



IMMUNE to shock and vibration.

Relay USRC 64-234 is said to surpass the environmental requirements of MIL-R-6106. Aided by its balanced magnetic structure, construction, and four-point suspension mounting, the relay withstands 30 g shock. It is hermetically sealed, operable in any position, and has optional solder or screw terminals. *U. S. Relay Company, 1744 Albion Street, Los Angeles 31, Calif.*

Characteristics

Contact Load (resistive)	25 amp at 29 vdc
Contact arrangement	1PDT
Coil voltage	24-28 vdc
Coil resistance	175 ohm
Dimensions	$2\frac{1}{16}$ x $1\frac{13}{32}$ x $1\frac{7}{16}$ in.
Weight	0.225 lb
Ambient temperature	−65 C-plus 125 C
Vibration immunity	up to 10 g at 10-500 cps.

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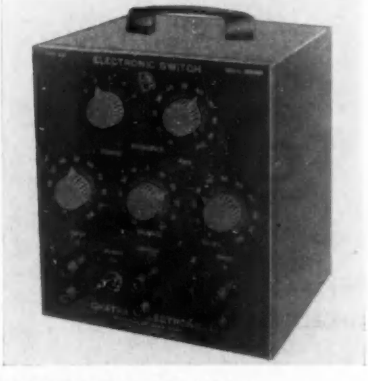

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(64) INDUSTRIAL COUNTERS, ETC. Atomic Instrument Co. Bulletin, 4 pp. Publicity literature on this bulletin tells of a brand new rapid counter, model 8003, that has a capacity of seven digits and maximum speed of 4,000 counts per sec or 240,000 per min. Counts can be continuous, discontinuous, random, or cyclic and flow can be linear or liquid. The bulletin itself does not show model 8003 but gives lowdown on other Atomic control units.

(65) ROTARY RELAYS. S. H. Couch Co., Relay Div. Bulletins 127 and 129, 4 pp. each. Mechanical, electrical, and environmental specifications are given for four- and two-pole double throw relays. Only differences here are resistance (6 millivolts for four-pole and 54 millivolts for two-pole) and the pull-in power of the dc coil (¼ watt at 25 deg C for first and ⅛ watt at 25 deg C for second). There are extensive tabular coil data.

(66) DC AMPLICATION SYSTEM. Weston Electrical Instrument Corp. Catalog B-36-A-3-55, 12 pp. Protagonist in this descriptive bulletin on Weston's Inductronic system is the Industronic dc amplifier. Other instruments for measurement and control whose specifications are covered here include the multi-range dc amplifier, sensitizing amplifier, integrating fluxmeter, knife-edge control unit, limit controller, and product resolver.

(67) FULLY- PROTECTED MOTOR. U. S. Electrical Motors, Inc. Booklet 1856, 12 pp. The interior of this new Type H Uniclosed motor is protected by a Ventrifoil at both air intakes. This guards the windings from water and allows liberal air flow. Except for more horsepower per cu. in., specifications do not differ from those for earlier model.

(68) TEMPERATURE CONTROLLER. Fenwal, Inc. Brochure MC-121, sheet. Available ranges for this series 511 remote bulb control unit are 60 to 250 deg F and 200 to 550 deg. F. Specialty is large electrical loads. Setting accuracy is plus or minus three per cent of the temperature range of the dial.

(69) "THIS IS SERVO." Servo Corp. of America. Pamphlet, 22 pp. The personnel, the instruments and systems, and some of the philosophy that have contributed to the short but fast growth of this New Hyde Park, N. Y. company receive handsome treatment in this attractive pamphlet. Displayed are Servo's three complete lines of industrial equipment: radio instruments, Servolab instruments, and infrared measurements.

(70) SOME DeJUR LITERATURE. DeJUR-Amsco Corp. Sheet MHD-155 describes the new 3½ in. sealed round elapsed time indicator, series HD-654. Sheet CO78 covers the new ⅞ in. subminiature precision potentiometer, series C-078. And a 4-pg. bulletin of the Electronic Sales Div. deals with the new miniature AN-type precision Continental connector with one-piece molded inserts.

(71) DATA REPEATER. General Motors Corp., AC Spark Plug Div. 6-pg. gatefold. The only information that need be furnished to these repeaters is a shaft position or a voltage source. The three fundamental types, single- and two-speed synchros, and potentiometer, work through 26 and 115 v motors (3,400 and 6,800

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maximum counts per min, respectively, in decimal display). Remote installation makes them suitable for aircraft, missiles, etc.

(72) INTERCOMMUNICATING SYSTEMS. Henschel Corp. Catalog 35 A, 8 pp. Transmitters and indicators, designed for 115 vac, 60 cycles, are listed according to sizes, pointers, catalog numbers, mountings, and types in a handy table toward the end of this black, white, and yellow booklet.

(73) AUTOMATIC SHELL MOLDING. Link-Belt Co., Book 2462, 8 pp. Here's a description of a new system that includes a four-station molding machine, a shell-closing machine, and all process equipment. Control panel contains motor starters, heater contactors, all solenoid valves, a master program timer, individual timers, and pushbuttons and pilot lights. Link-Belt says the system has proved itself in actual production.

(74) REGULATING VALVES. Maschinenfabrik Augsburg-Nurnberg A. G. Nuremberg Works. Bulletin 11 W 2, 4 pp. The pressure range of these German-made valves is 3-1.5 psi and the temperature range is 0.5-1 deg. C. The control factor is oil pressure through a servo motor. One valve can be made to respond to more than one regulating pressure.

(75) AUTRONIC COMPONENTS. Swartwout Co. Bulletin A1.4-1, 4 pp. The Autronic controller, centrally located, is the heart of this miniature, all-electronic control system. Cable to the controller can be of almost any length and signals can be run up to 15,000 ft. There are no moving parts in the controller, whose sensitivity is infinite, error plus or minus 0.5 per cent, and hysteresis zero. Controller input signal is 0.0-0.5 vac. Other components also illustrated and described.

(76) ROTAMETER EXTENSION TUBES. Brooks Rotameter Co. Bulletin 130, 9 pp. Feature of this pamphlet on armored rotameters are the new, non-magnetic metal extension tubes developed for the AR/MET rotameter, a rugged unit for hard-to-handle fluids. These extensions, MAG/NA/VUE and MAG/NA/LARM, can take pressures up to 1,000 psi and can be designed for even heavier work.

(77) COIL WINDER CATALOG. Geo. Stevens Mfg. Co. Catalog 55, 58 pp. Coils that are wound by the machines described in this attractive, cardboard-covered publication include armatures, transformers, bobbins, repeaters, solenoids, resistors, lattice-wound universals, and space-wound, variable pitch, toroidal, deflection yoke, and field coils. Among accessories covered are tensions, counters, wire guides, and gears and cams. There is a page of winding formulas and three pages of prices.

(78) INFORMATION FROM TRANSITRON. Transitron Electronic Corp. Bulletin TE 1320 contains eight specification sheets on transistors, Bulletin TE 1321 has three on silicon rectifiers, and two individual sheets, Bulletin TE 1322 and one not numbered, deal respectively with silicon junction diodes and products of both silicon and germanium. In the latter, the bulletin number follows transistor, diode, or rectifier described.

(79) PANELS AND PYROMETERS. Assembly Products, Inc. Bulletin G-9, 8 pp. Specifications, prices, and styles are given here for pyrometers and clear plastic- and black bakelite-cased panel meters. Standard error of the meters is plus or minus two per cent ac and plus or minus three per cent dc, with plus or minus 20 per cent resistance. Higher error at reduced price and less resistance at increased price.

(80) ANALOG COMPUTERS. Reeves Instrument Corp. Bulletin 25C-8-53, 4 pp. Tells about two new series, the 200 and 300. Three models of the 200: one with 24 computing amplifiers and two with 20 computing amplifiers and four servos; two models of the 300 (portable): both with 12 computing amplifiers. The 200 models will solve differential equations or simulate physical systems up through the seventh order; the 300's will solve ordinary linear differential equations through the sixth order and can be equipped for higher orders. All models enclosed in new A200 dual computing amplifier chassis.

(81) MAGNETIC STORAGE DRUMS. Remington Rand, Inc., Engineering Research Associates Div. Bulletin PX-71843, 4 pp. RemRand says these storage drums are the only ones commercially available whose data are not affected by power failure. A maximum of 2,522,000 spots in binary representation, or 500,000 alphanumeric characters is possible. Certain models can write or read at any spot in a matter of milliseconds. Specifications included.

(82) RELAY AND SWITCHES. Proebsting, Taylor, Inc. Catalog supplement, "Relay Highlights No. 4," one sheet. Here's how two P-T automatic electric rotary stepping switches proved out in a Cincinnati drilling machine company.

dc for introduction into ac amplifiers; and electronic switching of two signals for oscilloscope presentation superimposed or separated by any desired amount. There is 2 times gain amplification in the amplifier section. The electronic switch goes to 20,000 cps, and the amplifiers are flat within one db up to 150,000 cps. *Chatham Electronics Div. of Gera Corp., Livingston, N. J.*

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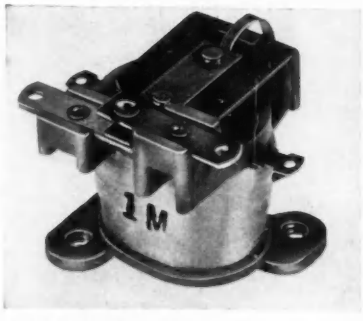

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Primarily intended for consumer products where its near-75 cent price will make a difference, this relay measures only slightly more than an inch on all sides, carries one amp on its contacts, and works on 50 milliwatts. *Sigma Instruments, Inc., 81 Pearl Street, South Braintree, Boston 85, Mass.*

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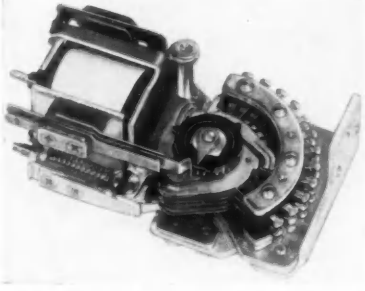

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Double Coil for up to 53 form A or up to 32 form B or form C

Operate Speed—25 to 75 milliseconds depending upon spring load and coil arrangement.

Also available with rectifier conversion units for A.C. relay operation having 10 to 32 form A contacts or 10 to 16 form B or form C contacts. Size, both A.C. and D.C. types, 4-5/16" x 5" x 1-27/32".

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Characteristics

Overall Length . . . . . $4\frac{13}{32}$ in.
Height . . . . . $2\frac{5}{16}$ in.
Width (depend on no. of banks) . . $2\frac{1}{8}$ in. (max.)
Hermetically sealed enclosure available.

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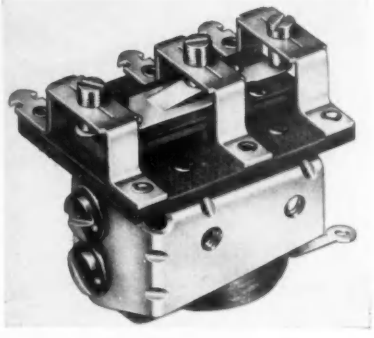

MINIATURE RELAY is sensitive, rugged, adjustable.

Balanced armature and adjustable contacts augment the sensitivity of the Type SO miniature relay. Factory set to operate on ten milliwatts, the contacts can be regulated in the field for operation on as little as two milliwatts. A life expectancy of 250,000 operations at a contact rating of 1.5 amp is claimed. Maximum allowable coil rating is three watts and temperature range extends from minus 55 C to plus 85 C. The relay is available in a variety of enclosures. *Advance Electric and Relay Co., 2435 North Naomi Street, Burbank, Calif.*

Characteristics

Contact Arrangement . . . . . SPDT
Contact Load . . . . . 1.5 amp
Coil Resistance (standard) . . 4,000, 6,500, and 10,000 ohm
Weight . . . . . 1.5 oz.
Dimensions . . . . . $1\frac{1}{4}$ x $1\frac{3}{32}$ x $1\frac{1}{4}$ in.
Vibration resistance . . . . . 20 g at 10-55 cps 5 g at 10-500 cps
Shock resistance 10g

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ERROR IN JUNE

The wrong cut was used for Item 38 in June New Products. A barrel-like pressure regulator, not a probe, is made by Beacon Devices, Inc.

Rememberance in Neon

From "Gas Diode Circuits for Electronic Computers," National Bureau of Standards, Summary Technical Report. U. S. Department of Commerce, Washington 25, D. C. April 1955

The cold-cathode gas diode—such as the simple neon glow lamp—offers possibilities for very large, low-cost, high-speed memories, once the inherent disadvantages of the tubes are overcome. A. W. Holt and D. C. Friedman of the National Bureau of Standards data processing systems laboratories are studying these visual-indicating tubes for memory and indicator circuits. The results so far are several circuits that may reduce the cost of digital computer memories from the present dollar per bit (binary digit) to about 10 cents per bit.

The cold-cathode gas diode has these advantages as a computer element: it is small, rugged, cheap, and cool-operating; it has low power requirements, high possible pulse power; and it affords visual indication and several types of possible binary states of operation. But it also has a number of disadvantages that limit its use: a wide range of characteristic potentials; variability of these potentials with use, ambient light, and temperature; long deionization time; and difficult access to a single bit when used in a matrix.

The basic gas diode circuit is shown in Figure 1. When used as a dc indicator memory bit, a potential somewhere between the firing and holding voltages is applied at point A. If the tube is unfired, this potential is not enough to cause conduction and the tube will remain dark. This corresponds to the binary zero. *B* is at the supply voltage and *C* is at ground.

If a positive voltage is applied momentarily at *A* or *B*, or a negative voltage is applied at *C*, the tube will fire. Point *B* drops in potential while point *C* rises, and the new levels will be maintained as long as *A* is above the holding potential for the tube. This is the binary one state. To return to the binary zero, the holding potential at *A* must be interrupted long enough for the tube to deionize fully. This is a disadvantage.

Figure 2 shows a double-diode memory circuit. A dc voltage above the firing potential is applied to *A*; thus one tube will always be on. To write in the opposite digit, the cathode of the "off" tube is pulled down with a negative "write" pulse, which causes it to fire. This causes the common point *B* to drop to near ground potential so that the "on" bulb has less than holding potential and starts to deionize. At the end of the "write" pulse point *B* again rises to holding potential, but all the current goes through the "on" bulb while the other continues toward the fully deionized state. Since the system is symmetrical, fast writing is possible in either direction.

Figure 3 shows the organization of the double gas-diode-capacitor-memory. This circuit is a variation of the NBS junction-diode-capacitor memory. Here the semi-conductor diodes are replaced by gas diodes. The gas diodes either clamp one side of the

Fig. 1

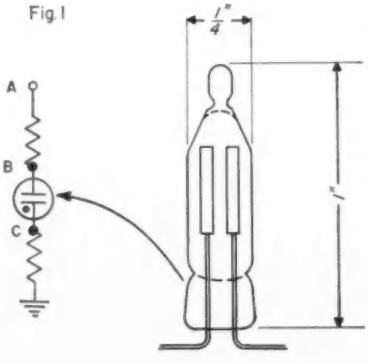
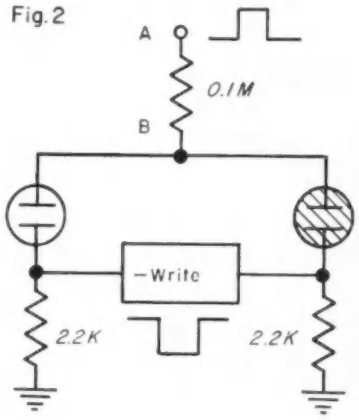


Fig. 2



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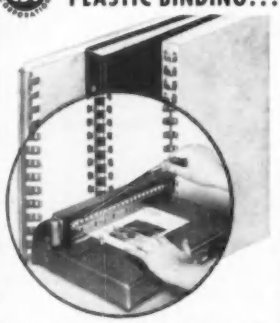

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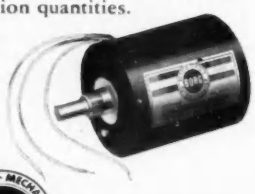

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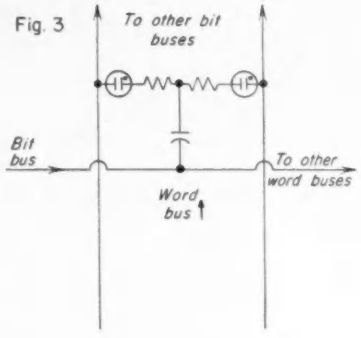
ABSTRACTS



storage capacitor or disconnect it.

In operation, the capacitor is charged a few volts positive for a binary one or a few volts negative for a binary zero. To write a one, the diodes are fired, clamping the top of the capacitor to approximately ground potential, and the bottom is pulled downward to minus 25 v. When the clamping pulses are terminated, the tubes deionize and disconnect the top of the capacitor. The bottom pulse is then released, raising the top of the capacitor to plus 25 v.

Similarly, to write a zero, a positive bottom write pulse is used. The circuit is read by clamping the top of the capacitor and noting the polarity of the pulse at the input to the read amplifier.

Theory Smooth and Turbulent

From "Theory of Hydraulic Flow Control," an article by Nils M. Sverdrup, Aerojet-General Corp. "Product Engineering," April 1955, pp. 161-176

Rate of flow in a hydraulic circuit depends on the resistances of its various components and the pressure differential across it. This article derives the equations of flow for any circuit, whether series or parallel, as well as the equations for the throttling orifice of a flow control valve.

Practical problems in the experimental determination of hydraulic resistance are discussed. These include the effect of laminar and turbulent flow on the coefficient of friction. Charts of coefficient of friction versus Reynolds number for laminar and turbulent flow in smooth pipes are included.

Separation occurs in value throttling orifices and venturi tubes when corners are too sharp or conical walls diverge too quickly. The results are

eddies and increased turbulence and energy dissipated as heat.

Cavitation occurs when the static pressure gets below the vapor pressure of the liquid. The liquid then vaporizes and a cavity filled with vapor forms. Sudden collapse of the cavities when the liquid enters a region of higher pressure causes very high shock forces and erosion of metal surfaces. Once cavitation is established, the rate of flow through a venturi remains constant regardless of further decrease in downstream pressure. This characteristic of the venturi is sometimes used to limit the flow rate.

Six numerical examples apply the equations to design problems and point out certain approximations which are useful.

More on Gamma Ray Gauges

From "A Gamma Ray Thickness Gauge For Hot Steel Strips and Tubes," by G. Syke. Journal of the British Institution of Radio Engineers, September 1954.

Close control of materials traveling at high speeds and temperatures is accomplished by non-contacting radiation gauges. Two applications of this scheme, from England, supplement a recent American article, "Use Radioactive Instruments," CONTROL ENGINEERING, March, 1955. Distinct readings at short time intervals display the longitudinal profile of a 600 ft hot steel strip, traveling at 1,200 ft/min. Coded lights indicate mean thickness of each interval, enabling the operator to adjust rolling mill gap and temperature distribution along the strip. The objective of the process is correct thickness (0.50 to 0.30 in.) throughout the length and width of the steel strip.

Steel thickness greater than 0.050 in. requires gamma or X-rays for penetration. For the application above, the gamma ray advantages (small size, lower cost, no connections, less vulnerability, no source stabilization, and no cooling) outweigh those of X-rays. Limitations of gamma rays are inadequate choice of energy spectra and limited source strength.

The source used in the gauge is thulium 170, with a half-life of 127 days and a useful life of four to six months. The detector consists of a sodium iodide crystal and photo-multiplier. The source is totally enclosed in an aluminum capsule, and the detector is mounted inside a shockproof, water-jacketed, welded steel structure.

The gamma source and detector are placed on opposite sides of the

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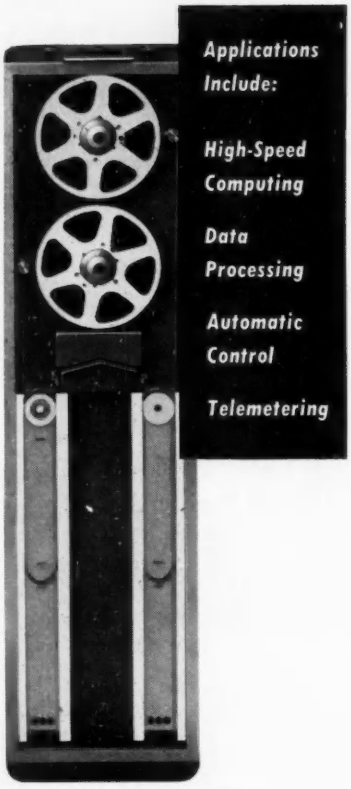

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ABSTRACTS

moving steel strip; the leading edge triggers a photocell circuit which energizes the measuring circuit and opens the shutter in the path of the gamma ray beam. At the proper moment registered pulses from the source feed definite charges to an integrating capacitor. The voltage across the capacitor, obtained during interval t_1, is a measure of the strip mean thickness. At the end of the interval, a definite fraction of the charge is transferred to a sharing capacitor and the first capacitor is discharged. This sequence is repeated several times. However, during the second interval the charge on the sharing capacitor is compared with a standard voltage, preset to the equivalent thickness. The magnitude of the difference voltage is a measure of the thickness error; this voltage is fed through biased tube and relay circuits, which, in turn, energize a coded light signifying the range of error.

The circuit continues to repeat the operation—measuring during one interval and comparing during the measurement of the succeeding interval. A timer and stepping switch arrangement cycles the operation, spreading the error light for succeeding intervals on adjacent rows of lights in the display panel.

The lamp board consists of five horizontal rows and 23 or 48 vertical columns of lamps to display the longitudinal profile. The middle lamp in each row is green, and when it is "on" the mean thickness in that interval is within the nominal setting and tolerance. Amber and red lights above and below the green indicate plus and minus thickness errors to preset ranges. A typical 600 ft strip, moving at 1,200 ft/min, will pass through the mill in 30 sec. During this time eighteen lamps, one for each 32 ft section, will light up. Observation of the longitudinal profile tells the operator the necessary corrections to make for the next strip.

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Recording the Bull

From "The Automatic Recording of Animal Behaviour in the Field," by R. J. Canway, W. F. Raymond, and J. C. Tayler, all of Grassland Research Institute, Herley, Berkshire, England. Electronic Engineering, March 1955.

A young bull that closed its own loop (sometimes by sitting on it) provided observers with valuable information on the time it spent in walking, standing, lying, grazing, chewing, and moving its legs and jaw. The idea was to see if these movements had any relation to productivity. A 5 lb "package" of recording equipment and switches, saddled to the bull, had these advantages:

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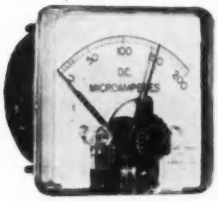

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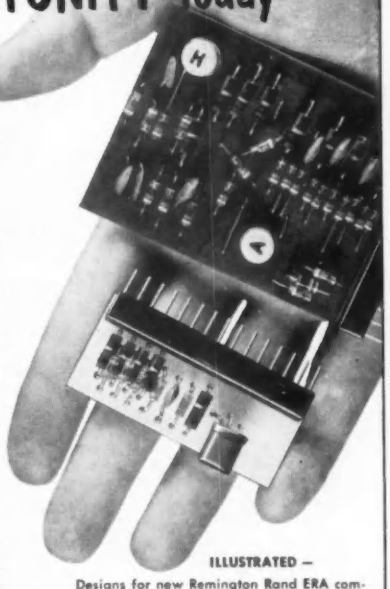

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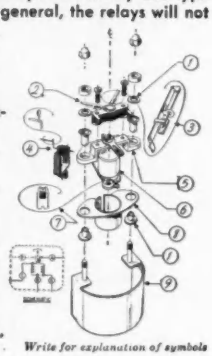

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WHAT'S AHEAD: MEETINGS

JUNE

American Society of Mechanical Engineers, Diamond Jubilee Semi-Annual Meeting, IRD Session on Thermodynamics, Hotel Statler, Boston, Mass. June 19-23

Institute of the Aeronautical Sciences, International Aeronautical Conference, Institute of Aeronautics Science Building, Los Angeles, Calif. June 20-23

American Institute of Electrical Engineers, Summer General Meeting, New Ocean House, Swampscott, Mass. June 27-July 1

Third British Instrument Industries Exposition, Earl's Court, London, F. W. Bridges & Sons, Ltd. Trafalgar Square, London W. C. 2 England. June 28-July 9

AUGUST

American Institute of Electrical Engineers, Pacific General Meeting, Butte, Mont. Aug. 15-19

Stanford Research Institute and National Industrial Conference Board, Symposium on Electronics and Automatic Production, Sheraton Palace Hotel, San Francisco, Calif. Aug. 22-23

Western Electronics Show and Convention, San Francisco Civic Auditorium, San Francisco, Calif. Aug. 24-26

SEPTEMBER

Production Engineering Show and Machine Tool Show, Navy Pier and International Amphitheater, Chicago, Ill. Sept, 6-16

Instrument Society of America, 10th Annual Conference and Exhibit, Shrine Exposition Hall and Auditorium, Los Angeles, Calif. Sept. 12-16

International Analogy Computation Meeting, Brussels, Belgium. Write P. Germain, Universite Libre de Bruxelles, So av. Fr. Roosevelt, Brussels, Belgium. Sept.27-Oct. 1

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RESEARCH IN NON-LINEAR MECHANICS AS APPLIED TO SERVOMECHANISMS. *Wright Air Development Center, U. S. Air Force 148 pp., illustrated. (Order PB 111584 from OTS, U. S. Department of Commerce, Washington 25, D. C.).* $3.75

This report describes the results of work for the U. S. Air Force by Cook Electric Co. aimed at improvement of servomechanism response by non-linear techniques. Included in the approach: development of practical non-linear elements to instrument these techniques, extension of non-linear theory through theoretical analysis, and formulation of non-linear servo theory into practical design information.

Cook reports that dual-mode operation is feasible not only for instrument servos, but for servos having ratings as high as ¼ hp. The report develops switching criteria for higher-order systems. A continuous controller is synthesized by network methods to replace the discontinuous controller usually used in the dual-mode system.

The optimum size and shape of the boundary between the outer and inner modes of a dual-mode servo are described and germanium diodes for use in servo-applied demodulators are evaluated.

Index to Pressure Dynamics

BIBLIOGRAPHY AND INDEX ON DYNAMIC PRESSURE MEASUREMENT. *National Bureau of Standards Circular 558, compiled by W. G. Brombacher and T. W. Lashof, 124 pp. Published by Government Printing Office, Washington 25, D. C. 75 cents.*

The bibliography in this circular contains 850 items on dynamic pressure measurement alone. Related subjects such as static pressure measurement and components of instruments are also covered, though in less detail. The references are extensively indexed and classified by subject and author to assist in detailed analyses. The bibliography may also serve as the starting point for surveys of more specialized parts of the subject.

Preparation of the bibliography was part of a cooperative program of development and research in basic instrumentation sponsored by the Office of Naval Research, Office of Scientic Research of the Air Research and Development Command, and the Atomic Energy Commission.

(Foreign remittances sent to the Government Printing Office for this publication must be in U. S. exchange and include an additional one-third of the price to cover mailing costs.)

Up to Date on AC

THE THEORY OF ALTERNATING CURRENT MACHINERY. *By Alexander S. Langsdorf, Washington University. New Second Edition 6 x 9 in., 666 pp. Published by McGraw-Hill Book Company, New York.* $8.50.

Two major points are recognized by the author in this revised edition: increased study in electronics limits the time available in engineering curricula for comprehensive courses in power machinery; and mercury-arc rectifiers have replaced the synchronous converter.

The book opens with the fundamental principles of the transformer; introductory discussions of circuit and field theory are eliminated. The author believes that transformer theory leads to better understanding of the principles of synchronous and asynchronous rotating machinery. Chapters on the various machines distinguish between fundamentals, and operational, structural, and design features. With the three chapters (of sixteen) on basic principles under his belt, the student can proceed to discussions of special machines in the latter chapters.

The new section on mercury-arc rectifiers and inverters includes the derivation of a simple formula for the separate and combined effects of overlap and phase control on voltage regulation. This material is not found in other American texts.

Aptly suited as a text, refresher, or reference, the book is well-written and easily understood. The author gracefully interjects practical aspects of measuring machine parameters and losses and advises on personnel and instrument safety.

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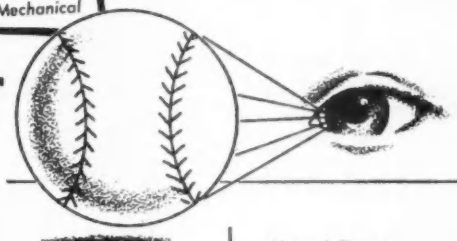

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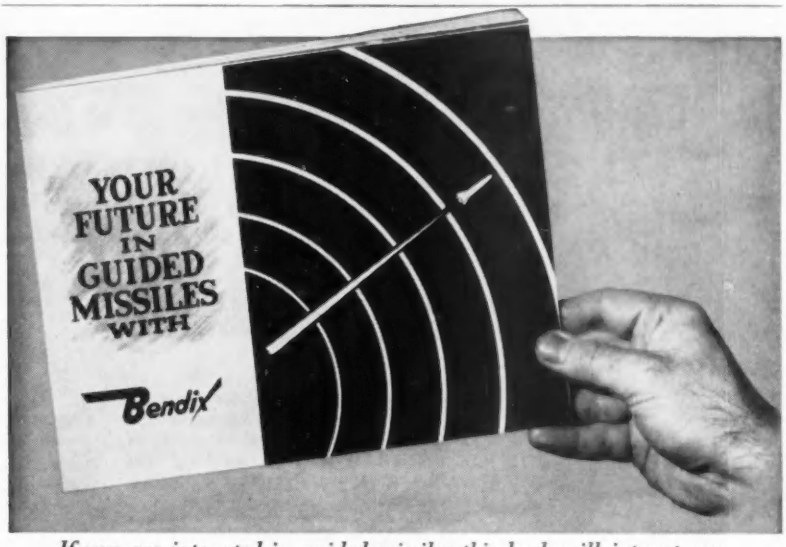

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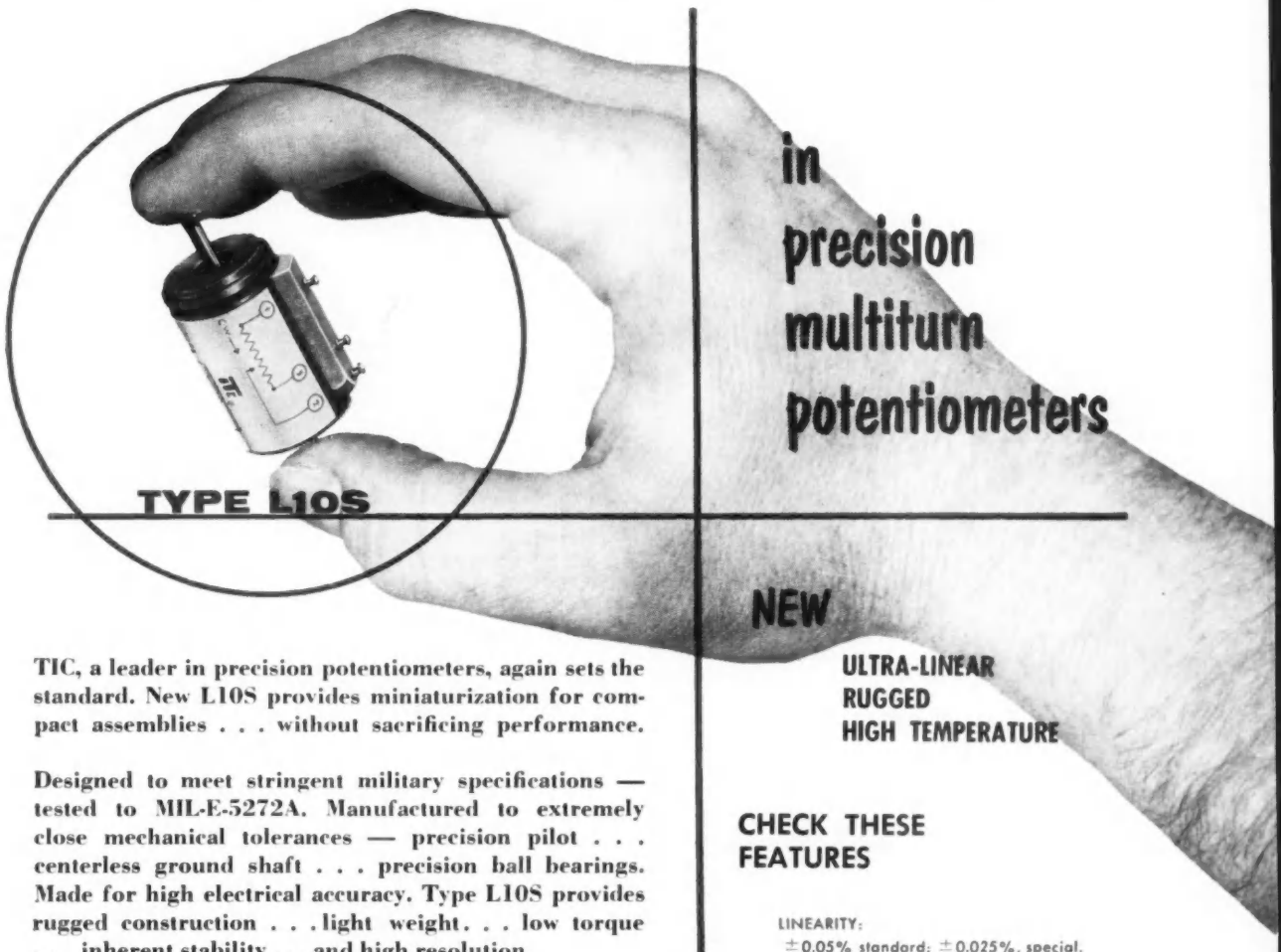

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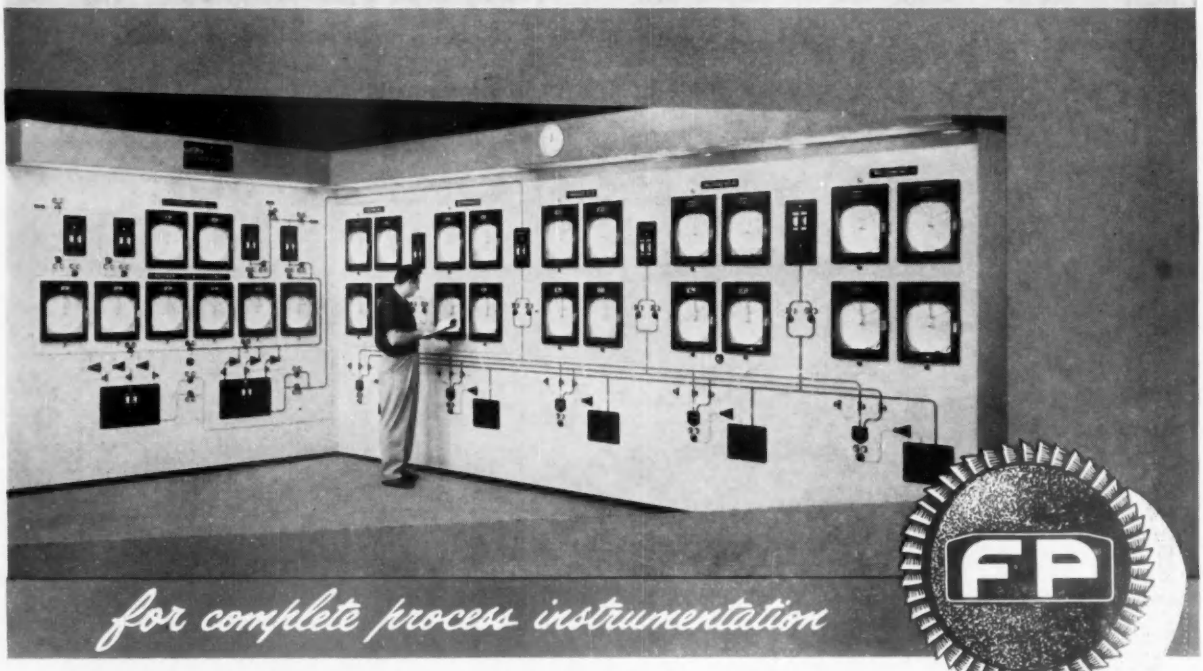

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